DRAFT

Third Party
Best Management Practice
Retrofit Pilot Study
Cost Review

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Prepared for:

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I. INTRODUCTION

In 1997, the California Department of Transportation (Caltrans) was directed by court order to conduct a Best Management Practice (BMP) Retrofit Pilot Program (Pilot Program) to study and evaluate a variety of permanent structural storm water BMP devices. In September 1999, Caltrans issued the *BMP Retrofit Pilot Studies – Technical Information* packet that summarized the elements of the Pilot Program that were conducted under that court order. In that document, Caltrans stated that the goal of the Pilot Program was "to determine the cost-effectiveness and water quality benefits of structural BMPs."

The court order stipulated that a broad base of "state-of-the-art" BMP technologies were to be incorporated into the Pilot Program. To satisfy this requirement, Caltrans identified 13 BMP device types representing a range of storm water protection approaches and methods.

Caltrans conducted scoping and site studies to select appropriate locations for construction of the selected storm water BMP devices. Sites were selected from the State right-of-way along freeways, within freeway interchanges, at Park & Ride sites, and at Caltrans Maintenance stations. As a result of these studies, Caltrans selected 21 sites in District 7 (Los Angeles) and 12 sites in District 11 (San Diego). A total of 39 BMP installations (individual structures) were identified to be constructed as part of the Pilot Program, with 26 devices constructed in District 7 and 13 constructed in District 11.

The BMP families, BMP types, and number of devices installed for the Pilot Program are listed in the following table.

BMP Family	BMP Type	No. of Devices Constructed
Biofilters	Biofiltration Strip	3
	Biofiltration Swale	6
Inlet Protection	Drain Inlet Insert	6
Media Filters	Storm Filter	1
	Delaware Sand Filter	1
	Austin Sand Filter	6
	Multi-Chamber Treatment Train	3
Basins	Extended Detention Basin	5
	Infiltration Basin	2
	Wet Basin	1
Other Technologies	Infiltration Trench/Strip	2
	Continuous Deflection Separator	2
	Oil Water Separator	1
Total Number of BMP Devices Constructed:		39

Additional studies were made to determine site-specific design criteria for each of the 39 BMP installations to be constructed including:

- Retrofit requirements
- Actual construction costs
- Design and administrative issues
- Efficiency of constituent removal
- Operation and maintenance requirements

Based on these analyses, Caltrans estimated construction costs of $5 million dollars for District 7 and $4 million dollars for District 11.

Construction of the BMP devices for the Pilot Program began in September 1998 and was substantially complete in March 1999. For the duration of the program, Caltrans maintained detailed records to document costs and issues related to siting; design; bidding; construction; and operation, maintenance, and monitoring (OMM). Deviations from BMP standard designs to accommodate site-specific constraints were also documented. OMM plans were developed to ensure that project data were collected uniformly and according to established protocols. Based on these records, Caltrans total construction costs for the Pilot Program were $4,877,480 for District 7 and $4,113,287 for District 11 for a total of $8,990,767.

To analyze the costs associated with the Caltrans Pilot Program, a third party review was conducted. Holmes & Narver, Inc. and Glenrose Engineering were selected to conduct the study. This report contains the results of their independent analysis of the costs associated with the construction, and operation and maintenance (O&M) of the BMP devices implemented in the Pilot Program and presents cost-reducing strategies used by other transportation agencies experienced with the construction of the BMP devices within the families in the Pilot Program.

A. Organization of the Report

This report is organized as follows:

- Section I — Introduction to the report
- Section II.A — Analysis of the total cost of construction in the Pilot Program
- Section II.B — Analysis of the total construction cost of BMP installations in the Pilot Program
- Section II.C — Analysis of the construction cost of BMP installations excluding costs specific to the Pilot Program
- Section II.D — Projected construction cost of each BMP installation based on unit cost curves among similar BMP devices
- Section II.E — Projected O&M cost of each BMP installation based on unit cost curves among similar BMP devices
- Section II.F — Section II Conclusions
- Section III — Strategies used by other agencies to reduce costs related to permanent structural device BMP construction and O&M

- Section IV Comparison and analysis of Caltrans construction and O&M costs for the Pilot Program with the costs experienced by other agencies

B. Questions for Third Party Consideration

Prior to beginning the study, the third party team was given a set of questions to define the scope of the report. The initial set of questions provided a starting point for the focus of the study, allowing questions to be added, deleted or modified as the study proceeded. Changes to questions required consensus from all parties prior to adoption. The third party study attempted to address all issues raised by the final set of questions.

The final set of questions is listed below with a reference to the section(s) of the report that address each question. The order of the questions does not suggest a weighting of the importance of a particular question.

Questions for Third Party Consideration	Addressed in Section
• How could Pilot Program designs and material components be simplified and/or standardized to lower BMP costs?	III
• How could changes in the methods used in the Pilot Program to present information to, select and work with construction contractors affect BMP costs?	III
• Are there cost savings that could be realized through different scaling of BMP deployment (larger or smaller drainage area potentially involving joint use)?	II.D & III
• How did the accelerated time of completion under the Pilot Program affect costs?	II.C
• How did the requirement to build a small number of each type of BMPs for the Pilot Program affect costs?	III
• What design modifications could be used on Pilot Program BMPs to lower costs in future applications?	III
• Within the tested family of BMPs, how could experiences of other transportation agencies (DOTs) and jurisdictions be used to lower construction and O&M costs?	III & IV
• What is the most appropriate design storm/water quality volume as it might be used to define deployment criteria for the family of technologies piloted?	III
• How would the information learned in designing the pilots affect future BMP costs?	II.C
• How will increased familiarity and experience with BMPs by construction contractors affect future BMP costs?	II.C
• How will the elimination of monitoring and other pilot-unique requirements affect future BMP costs?	II.B
• How can lessons learned during the Pilot Program help reduce construction cost?	II.C & II.D

• How will the construction of BMPs on a larger scale than the Pilot Program affect costs?	III & IV
• How can ancillary costs not directly attributable to BMP construction (e.g., maintenance or improvements to existing Caltrans infrastructure) best be accounted for?	II.B
• How would the use of Caltrans labor rather than contract labor affect O&M costs?	II.D
• How do Pilot Project O&M costs and level of effort (labor hours) compare with those of other DOTs and public agencies in the U.S.?	III
• How do the Caltrans pilot BMP construction costs compare with national BMP costs (other DOTs and U.S. jurisdictions)?	IV
• If other organizations' BMP construction costs are significantly different, what elements account for these differences?	IV
• Considered within the context of California contracting regulations and prevailing wage rates in Southern California, how can cost-saving elements from other agencies be transferred to Caltrans to lower BMP costs?	IV

C. Definitions and Assumptions

The following terms are used in the report to define the BMP construction processes:

• Inline (Piggyback) Construction	Construction of a BMP device within an existing flood control facility
• New Construction	Construction of a BMP device in conjunction with the construction of a new facility
• Redevelopment	Construction of a BMP device in conjunction with the major reconstruction of an existing facility
• Retrofit	Construction of a BMP device by fitting an existing facility

The following terms are used in the report to identify the various analyses of construction costs associated with the Caltrans Pilot Program:

• Total Pilot Program Construction Cost	Total cost to construct the BMP device as a retrofit as specified in the Pilot Program. This total includes costs unique to the Pilot Program for monitoring and for other Pilot Program requirements. It also includes Ancillary Costs (miscellaneous non-BMP costs) as described in Section II.A2.

- Actual Construction Cost — Cost to construct the BMP structure as a retrofit as specified in the Pilot Program, excluding unique costs due to Pilot Program BMP Monitoring requirements and Ancillary Costs.
- Adjusted Construction Cost — Cost to construct the BMP structure as a retrofit at the same location, excluding all costs associated with unique Pilot Program requirements (monitoring and non-monitoring costs) and Ancillary Costs.
- Projected Construction Cost — Estimated cost to construct a similar BMP device as a retrofit at an existing facility.

The following assumptions should be considered when reviewing the costs analyses conducted for the study:

- All cost information presented in the tables and graphs in this report represent best estimates generated from available data.
- The costs presented for the Pilot Program BMP installations are based on actual construction cost data, including: state-furnished materials, Contract Change Order (CCO) information, contract plans, Special Provisions, Caltrans Standard Specifications, and engineers' estimates.
- The costs presented for BMP installations constructed by other agencies are based on the following data:
  - Contract plans (Standard specifications and contract special provisions were not available.)
  - Costs generated from engineers' estimates or from bid tabulations. (Cost data does not represent actual construction costs.)
  - Costs do not include state-furnished materials or any CCO cost information.
- The effectiveness of a BMP installation to remove pollutants was not considered as part of this study. It should be noted that for the other agencies included in this report, BMP effectiveness had not been specifically measured.
- Of the 39 BMP installations constructed as part of the Caltrans Pilot Program, only 37 were analyzed for Projected Construction Cost. Construction cost data for two BMP installations, number 36 (MFSD at the Paxton park and ride) and number 38 (MCTT at the Metro maintenance station), were not available for this report. O&M costs were also not included.
- The construction costs for BMP installations constructed in Los Angeles and San Diego are true costs for each location. No attempt was made to adjust the construction costs to either Los Angeles or San Diego. To adjust construction costs to Los Angeles from San Diego a location factor of 1.028 would apply.

II. BMP PILOT PROGRAM COST ANALYSIS

This section provides detailed information about the costs for the BMP installations constructed for the Caltrans Pilot Program conducted in Districts 7 and 11. Pilot Program construction costs include the sum of original contract "bid" items, state-furnished materials, and CCOs associated with unforeseen items of work. The O&M costs are also analyzed.

Much of the construction cost information presented in the tables of this section was derived from the *BMP Retrofit Pilot Program Construction Cost Summary Districts 7 and 11* prepared by Robert Bein, William Frost & Associates (RBF) which was prepared from the review of actual construction contract records. The O&M cost data were derived from the *BMP Retrofit Pilot Project Quarterly Status Report No. 10* prepared by RBF.

Analyzing the cost summaries, the contract plans, and Special Provisions for each BMP installation, the third party team allocated the construction costs of each BMP installation to specific cost categories. Many of the construction cost categories are developed from the Revised Pilot Unique Cost Table (December 6, 2000) provided in Attachment 1.

Caltrans construction costs for the Pilot Program are examined through a sequence of analyses to arrive at projected costs for future BMP construction. The following figure illustrates the analysis sequence. Each analysis is described in the following sections:

- Section II.A: Total Pilot Program Construction Cost Analysis
- Section II.B: Actual Pilot Program Construction Cost Analysis
- Section II.C: Adjusted Construction Cost Analysis
- Section II D: Projected Construction Cost Analysis
- Section II E: Projected Annual O&M Cost Analysis
- Section II F: Section II Conclusions

Each analysis includes a table with the detailed cost breakdown for each BMP installation by cost category. The accompanying text identifies the purpose of the cost analysis and definitions of the cost categories shown in the tables.

A detailed cost breakdown of the construction costs for each BMP installation of the Pilot Program is included in electronic format as a compact disk (CD).

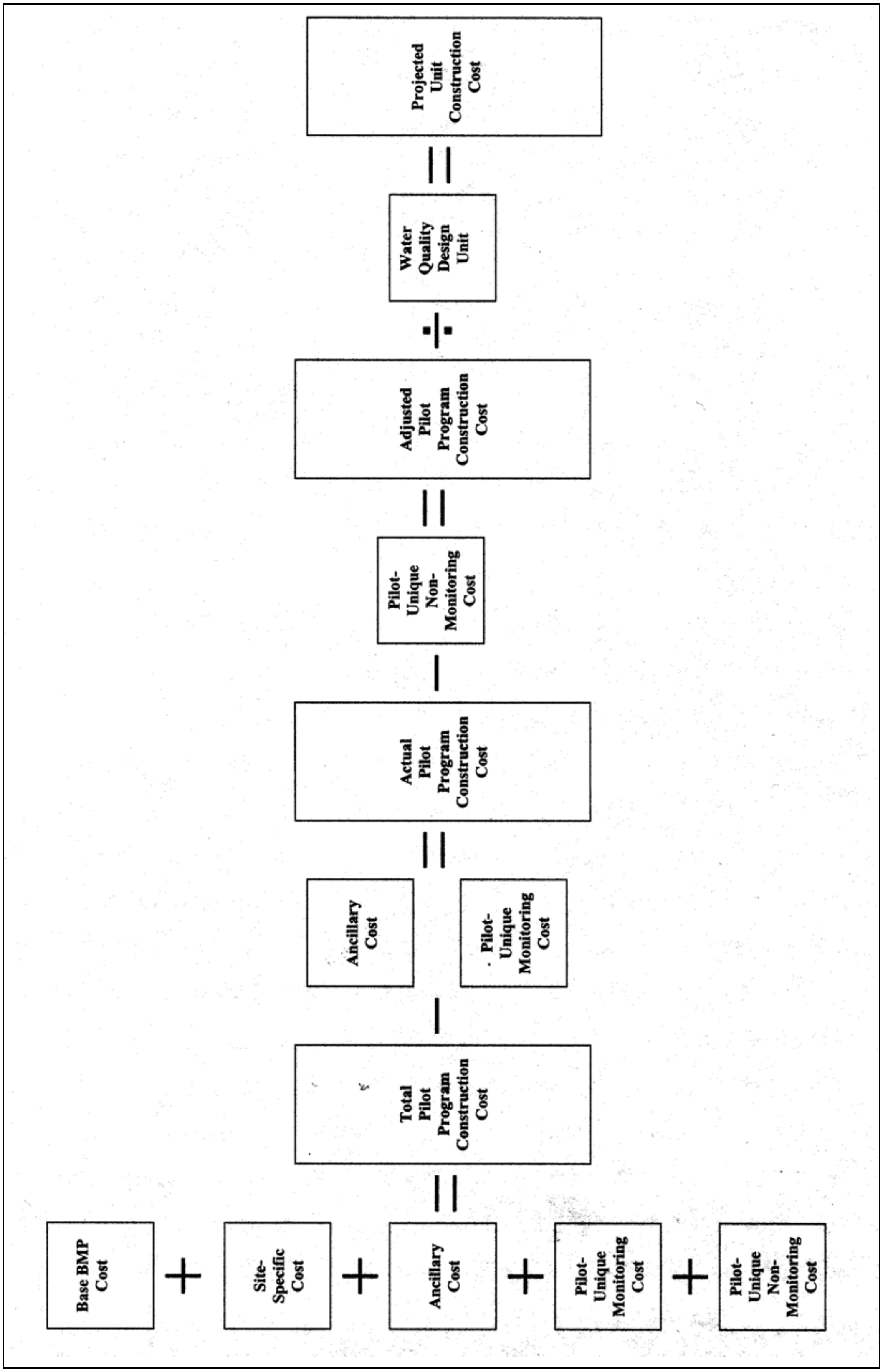


Figure 1 Pilot Program Construction Cost Analysis

A. Total Pilot Program Construction Cost Analysis

This section contains an analysis of all construction costs incurred by Caltrans for the 39 BMP installations in the Pilot Program. Table 1, **Total Pilot Program Construction Cost Breakdown**, shows the total cost associated with each BMP installation and breaks the total cost into the following five cost categories:

- Site Specific Costs
- Ancillary Costs
- Pilot Program Unique Monitoring Costs
- Pilot Program Unique Non-Monitoring Costs
- Base BMP Cost

Each of these construction cost categories is discussed below.

Table 1 contains the following information:

BMP No.: A number (1-39) assigned to each BMP installation for ease of reference.

WQ ID No.: Unique Water Quality (WQ) Site Identification (ID) Number assigned to the 39 BMP installations that identifies the following information:

- The first two digits identify the Caltrans District in which the BMP is located:
  07 – District 7, Los Angeles
  11 – District 11, San Diego
- The third digit identifies the design firm:
  1 or 2 – RBF
  3 – Montgomery Watson – Chaudhary (MW-C)
  4 – Brown and Caldwell (BC)
- The fourth digit identifies the construction contract type:
  1 – Plans, Specifications & Estimate (PS&E)
  2 – Procurement
- The fifth digit identifies the construction contract package with which the site was grouped:
  0 – No Package Number Assigned
  1 – Package 1 (MW-C sites only)
  2 – Package 2 (MW-C sites only)
- The sixth digit of the WQ ID Number identifies the specific site within a package. Some sites are additionally identified with an “a” or “b” where two BMPs devices are located at the same site.

BMP Type: The specific BMP device using the following abbreviations:

Device	Abbreviation
Biofiltration Strip	**BSTRP**
Biofiltration Swale	**BSW**
Continuous Deflection Separator	**CDS**
Drain Inlet Insert – Fossil Filter	**DII-FF**
Drain Inlet Insert - StreamGuard	**DII-SG**
Extended Detention Basin	**EDB**
Infiltration Basin	**IB**
Infiltration Trench with Bio Strip Pretreatment	**IT/STRP**
Multi-Chambered Treatment Train	**MCTT**
Media Filter – Storm Filter	**MFSTF**
Media Filter – Delaware	**MFSD**
Media Filter – Austin	**MFSA**
Oil-Water Separator	**OWS**
Wet Basin	**WB**

Site Location: The physical location of the BMP installation by road, highway, or Maintenance station name. The site location affected construction costs related to issues such as local agency involvement, special use permits, traffic control, demolition, and buried objects. Pilot BMP site locations ranged from dense urban settings, which were more heavily impacted by these issues, to less urban settings, with relatively few of these impacts.

Facility Type: The type of facility where the BMP retrofit occurred.

Pilot Program Construction Cost:

Original Contract "Bid" Cost: The initial contract amount awarded for the construction of the BMP device. Bids for each site were obtained through the normal PS&E process or procurement process. The awarded amounts indicated in Table 1 reflect the following:

- The awarded amount is the low "bid" or a negotiated amount. In many cases, and for various reasons, negotiations with low bidders resulted in award amounts that were different from the low bids. Negotiated amounts were also awarded when the construction was performed as a CCO of another project.
- Multiple pilot sites may have been packaged into one construction contract. In these cases, contracts were awarded based on the low bid for the entire package, and not necessarily the low bid on a site-by-site basis. For example, for the MFSD at the Escondido Maintenance Station (BMP No. 7), the awarded amount was the highest bid for that site, but was part of the low packaged bid for seven sites.

- Eight BC procurement sites were bid as lump sums with the distribution of cost to each site negotiated after receipt of competitive bids.
- Where only a lump sum dollar amount was provided for a particular BMP installation, the amount was broken down into the specific items required to construct the BMP device. Using the third party team's experience in designing, estimating, and construction, estimated quantities and appropriate prices were established for each item equaling the "bid" lump sum.

State Furnished Materials: This amount represents the value of materials that were made available to the contractor free of charge. These materials do have an associated cost, but the cost was borne solely by Caltrans; therefore, these material costs were not represented in the submitted "bid". State Furnished Materials cost is identified as a separate cost for this report, but considered an integral part of the overall cost to construct the BMP installations.

Contract Change Orders: A process for which alterations, deviations, additions, and deletions from the plans and specifications of the original contract can be ordered by the Resident Engineer (RE). The CCO identifies the work to be done, adjustments to contract schedules, if any, and the basis for compensation for such work. Examples of work completed by CCO while constructing the pilot BMP devices include:

- Additional traffic control and flagging
- Additional earthwork; import of fill material
- Modifications to existing drainage facilities
- Removal of buried man-made objects and/or demolition of existing facilities not identified in the plans
- Additional fencing and gates
- Resolution of utility conflicts
- Additional landscaping and irrigation

Total Pilot Program Construction Cost: The sum of Original Contract "Bid" Cost, State Furnished Materials, and CCOs. This amount is the construction cost for each BMP installation constructed for the Caltrans BMP Retrofit Pilot Program. Design and construction engineering, administration and right-of-way costs are not included in this amount.

Pilot Program Construction Cost Breakdown

Site-Specific Cost: The construction costs associated with specific site conditions. Site-specific costs result from characteristics of an individual site that added difficulty to the design and construction process. These characteristics may be known before bid time or may become known after bid time. Examples of site specific conditions attributable to these costs included: urban settings, modifications to existing drainage systems, unique traffic or space constraints, topographic issues, geological issues, unknown buried objects, dewatering, and demolition of adjacent facilities. This category is described in more detail in Section II.A.1 and in Table 2.

Ancillary Cost: The construction costs associated with maintenance, repairs or upgrades to existing infrastructure that were accomplished while the construction crews and equipment were available on site. These are construction costs not directly attributable to the specific BMP installation. Examples of ancillary costs included minor improvements to access roads, landscaping or erosion control, and non-BMP related facilities. This category is described in more detail in Section II.A.2 and in Table 3.

Pilot-Unique Monitoring Cost: The construction costs associated with monitoring facilities required as a part of the Pilot Program. These costs are considered unique to the Pilot Program to determine performance benefits of the BMP device, and would not be incurred outside of the Pilot Program. Examples of monitoring costs included: construction of access points, construction of concrete equipment bases, construction of additional manholes, and specialized materials required for monitoring. This category is described in more detail in Section II.A.3 and Table 4.

Pilot-Unique Non-Monitoring Cost: The construction costs associated with the Pilot Program that are generally considered unique to the Pilot Program, and are not attributable to monitoring costs. Examples of such costs included designer and construction contractor's experience, accelerated time of completion, and contract method. In some instances, a negative value appears in this category to indicate unanticipated savings at a site. Although these costs and/or savings were identified as being directly related to the Pilot Program, it is conceivable that many of these factors could impact BMP device construction cost outside the Pilot Program, as well. This category is described in more detail in Section II.A.4 and Table 4.

Base BMP Cost: The cost directly attributable to the construction of the specific BMP device. This is the total Pilot Program construction cost less the site-specific cost, ancillary cost, pilot-unique monitoring cost, and pilot-unique non-monitoring cost. The Base BMP Cost is the construction cost of the BMP device, excluding any other possible contributing items associated with the construction.

TABLE 1 - TOTAL PILOT PROGRAM CONSTRUCTION COST BREAKDOWN

					E	F	G	H	I	J	K	L	M
								=E+F+G	See Table 2, Col R	See Table 3, Col H	See Table 4, Col J	See Table 4, Col Y	=H-I-J-K-L
					Pilot Program Construction Costs				Pilot Program Construction Cost Breakdown				
BMP No.	WQ ID No.	BMP Type	Site Location	Facility Type	Original Contract "Bid" Cost	State Furnished Materials	CCOs	Total Pilot Program Construction Cost	Site-Specific Cost	Ancillary Cost	Pilot-Unique Monitoring Cost	Pilot-Unique Non-Monitoring Cost	Base BMP Cost
San Diego Area, District 11													
1	111105	EDB	I-5/Manchester (east)	Highway	335,406	12,742	22,260	$ 370,408	$ 206,978	$ -	$ 23,098	$ 77,602	$ 62,730
2	111101	EDB	I-5/SR 56	Highway	132,399	-	29,455	$ 161,853	$ 77,404	$ -	$ 22,015	$ 10,082	$ 52,353
3	111102	EDB	I-15/SR 78	Highway	653,676	-	194,036	$ 847,712	$ 497,514	$ -	$ 54,407	$ 76,602	$ 219,188
4	111103	IB	I-5/La Costa (west)	Highway	210,229	3,700	58,748	$ 272,677	$ 194,365	$ -	$ 11,371	$ 38,254	$ 28,686
5	111104	WB	I-5/La Costa (east)	Highway	602,158	46,386	59,981	$ 708,525	$ 309,403	$ 19,359	$ 55,138	$ 85,329	$ 239,297
6	112201	MFSTF	Kearny Mesa Maint. Station	Maint Station	298,797	-	26,721	$ 325,518	$ 57,029	$ -	$ 20,162	$ (7,343)	$ 255,670
7	112202	MFSD	Escondido Maint. Station	Maint Station	490,405	-	(37,392)	$ 453,013	$ 63,376	$ -	$ 55,477	$ 147,227	$ 186,933
8	112203	MFSA	La Costa Park & Ride	Park & Ride	208,955	-	30,722	$ 239,677	$ 91,855	$ -	$ 14,473	$ (3,606)	$ 136,956
9	112204	MFSA	SR 78/I-5 Park & Ride	Park & Ride	224,502	-	(1,973)	$ 222,529	$ 111,132	$ -	$ 13,933	$ (22,220)	$ 119,685
10	112205	BSW	SR 78/Melrose Dr	Highway	87,039	32,490	22,890	$ 142,419	$ 45,212	$ 3,881	$ 9,342	$ 47,672	$ 36,312
11	112206	BSW	I-5/Palomar Airport Rd	Highway	113,895	13,970	9,471	$ 137,336	$ 41,568	$ 23,634	$ 428	$ 12,786	$ 58,920
12	112207a	BSTRP	Carlsbad Maint. Station (west)	Maint Station	60,463	4,390	24,391	$ 89,243	$ 43,451	$ 22,299	$ 8,682	$ -	$ 14,810
13	112207b	IT/STRP	Carlsbad Maint. Station (east)	Maint Station	97,338	10,899	34,139	$ 142,376	$ 58,914	$ 22,299	$ 23,218	$ 347	$ 37,599
Los Angeles Area, District 07													
14	073211a	BSTRP	Altadena Maint. Station	Maint Station	88,339	3,865	54,196	$ 146,400	$ 76,399	$ -	$ 40,052	$ 3,964	$ 25,985
15	073211b	IT/STRP	Altadena Maint. Station	Maint Station	223,919	3,865	65,804	$ 293,588	$ 159,255	$ -	$ 47,167	$ 4,820	$ 82,346
16	073216a	DII-SG	Foothill Maint. Station	Maint Station	29,529	-	(875)	$ 28,655	$ -	$ -	$ 27,555	$ 730	$ 370
17	073216b	DII-FF	Foothill Maint. Station	Maint Station	45,432	-	(329)	$ 45,104	$ -	$ -	$ 44,054	$ 679	$ 370
18	073217a	DII-SG	Las Flores Maint. Station	Maint Station	43,703	-	3,401	$ 47,104	$ -	$ -	$ 46,114	$ 620	$ 370
19	073217b	DII-FF	Las Flores Maint. Station	Maint Station	47,380	-	8,908	$ 56,288	$ -	$ -	$ 55,296	$ 623	$ 370
20	073218a	DII-SG	Rosemead Maint. Station	Maint Station	26,191	-	(1,013)	$ 25,177	$ -	$ -	$ 24,077	$ 730	$ 370
21	073218b	DIIFF	Rosemead Maint. Station	Maint Station	43,265	-	(4,210)	$ 39,055	$ -	$ -	$ 38,006	$ 679	$ 370
22	073222a	BSTRP	I-605/SR 91	Highway	119,708	16,440	21,025	$ 157,173	$ 33,429	$ -	$ 71,604	$ 21,820	$ 30,319
23	073222b	BSW	I-605/SR 91	Highway	47,428	5,444	11,670	$ 64,543	$ 15,723	$ -	$ 21,724	$ 3,654	$ 23,441
24	073223	BSW	Cerritos Maint. Station	Maint Station	57,873	1,288	1,221	$ 60,383	$ 12,808	$ -	$ 28,447	$ 3,595	$ 15,533
25	073224	BSW	I-5/I-605	Highway	124,722	7,727	(32,715)	$ 99,733	$ 28,972	$ -	$ 23,575	$ 24,345	$ 22,842
26	073225	BSW	I-605/Del Amo Ave	Highway	120,042	4,502	3,279	$ 127,823	$ 25,841	$ -	$ 57,237	$ 21,216	$ 23,529
27	073102	CDS	I-210/Orcas Ave	Highway	21,683	17,453	600	$ 39,736	$ 21,310	$ -	$ 8,052	$ (16,468)	$ 26,843
28	073103	CDS	I-210/Fillmore Ave	Highway	25,580	17,744	1,700	$ 45,024	$ 26,410	$ -	$ 9,343	$ (19,428)	$ 28,699
29	073101	IB	I-605/SR 91	Highway	255,646	-	12,484	$ 268,130	$ 148,797	$ 33,347	$ 150	$ 26,356	$ 59,480
30	074101	EDB	I-5/I-605 Intersection	Highway	146,647	-	23,085	$ 169,732	$ 77,917	$ -	$ 11,850	$ 46,355	$ 33,610
31	074102	EDB	I-605/SR 91 Intersection	Highway	92,376	-	19,495	$ 111,871	$ 64,475	$ -	$ 19,632	$ 155	$ 27,610
32	074201	OWS	Alameda Maint. Station	Maint Station	173,320	-	6,117	$ 179,437	$ 32,375	$ -	$ 16,055	$ 29,473	$ 101,534
33	074202	MFSA	Eastern Regional Maint. Sta.	Highway	248,806	-	104,896	$ 353,702	$ 84,445	$ -	$ 10,916	$ 81,872	$ 176,469
34	074203	MFSA	Foothill Maint. Station	Maint Station	375,537	-	110,409	$ 485,947	$ 172,806	$ -	$ 7,582	$ 79,071	$ 226,488
35	074204	MFSA	Termination Park & Ride	Park & Ride	356,080	-	115,558	$ 471,638	$ 93,237	$ -	$ 12,249	$ 79,287	$ 286,865
36	074103	MFSA	Paxton Park & Ride	Park & Ride	273,369	-	-	$ 273,369	$ -	$ -	$ -	$ -	$ 273,369
37	074206	MCTT	Via Verde Park & Ride	Park & Ride	286,266	-	97,527	$ 383,793	$ 85,172	$ -	$ 10,234	$ 74,895	$ 213,493
38	074104	MCTT	Metro Maint. Station	Maint Station	439,333	-	-	$ 439,333	$ -	$ -	$ -	$ -	$ 439,333
39	074208	MCTT	Lakewood Park & Ride	Park & Ride	360,061	-	104,682	$ 464,743	$ 83,255	$ -	$ 11,299	$ 74,319	$ 295,869
			Pilot Program Total		$ 7,587,496	$ 202,907	$1,200,365	$ 8,990,767	$ 3,040,827	$ 124,820	$ 954,015	$1,006,090	$3,865,015
	% Total Pilot Program Const. Cost				84%	2%	13%	100%	34%	1%	11%	11%	43%
	Average Cost by Facility Type =			All	$ 194,551	$ 5,203	$ 30,779	$ 230,532	$ 77,970	$ 3,201	$ 24,462	$ 25,797	$ 99,103
				Highway	$ 196,320	$ 10,506	$ 33,080	$ 239,906	$ 111,751	$ 4,719	$ 24,111	$ 31,659	$ 67,666
				Maint Station	$ 158,801	$ 1,519	$ 18,218	$ 178,539	$ 42,276	$ 2,787	$ 30,122	$ 16,576	$ 86,778
				Park & Ride	$ 284,872	$ -	$ 57,753	$ 342,625	$ 77,442	$ -	$ 10,365	$ 33,779	$ 221,039
	Average Cost by BMP Type =			EDB	$ 272,101	$ 2,548	$ 57,666	$ 332,315	$ 184,858	$ -	$ 26,201	$ 42,159	$ 79,098
				IB	$ 232,937	$ 1,850	$ 35,616	$ 270,403	$ 171,581	$ 16,674	$ 5,761	$ 32,305	$ 44,083
				WB	$ 602,158	$ 46,386	$ 59,981	$ 708,525	$ 309,403	$ 19,359	$ 55,138	$ 85,329	$ 239,297
				EDB, IB, WB	$ 303,567	$ 7,854	$ 52,443	$ 363,864	$ 197,107	$ 6,588	$ 24,708	$ 45,092	$ 90,369
				MFSTF	$ 298,797	$ -	$ 26,721	$ 325,518	$ 57,029	$ -	$ 20,162	$ (7,343)	$ 255,670
				MFSD	$ 490,405	$ -	$ (37,392)	$ 453,013	$ 63,376	$ -	$ 55,477	$ 147,227	$ 186,933
				MFSA	$ 281,208	$ -	$ 59,935	$ 341,144	$ 92,246	$ -	$ 9,859	$ 35,734	$ 203,305
				MCTT	$ 361,887	$ -	$ 67,403	$ 429,290	$ 56,142	$ -	$ 7,178	$ 49,738	$ 316,232
				MF STF,SD,SA,TT	$ 323,828	$ -	$ 50,105	$ 373,933	$ 76,574	$ -	$ 14,211	$ 45,773	$ 237,375
				BSW	$ 91,833	$ 10,904	$ 2,636	$ 105,373	$ 28,354	$ 4,586	$ 23,459	$ 18,878	$ 30,096
				BSTRP	$ 89,503	$ 8,232	$ 33,204	$ 130,938	$ 51,093	$ 7,433	$ 40,113	$ 8,595	$ 23,705
				BSW, BSTRP	$ 91,056	$ 10,013	$ 12,825	$ 113,895	$ 35,934	$ 5,535	$ 29,010	$ 15,450	$ 27,966
				IT/STRP	$ 160,628	$ 7,382	$ 49,971	$ 217,982	$ 109,084	$ 11,150	$ 35,192	$ 2,584	$ 59,973
				OWS	$ 173,320	$ -	$ 6,117	$ 179,437	$ 32,375	$ -	$ 16,055	$ 29,473	$ 101,534
				CDS	$ 23,632	$ 17,599	$ 1,150	$ 42,380	$ 23,860	$ -	$ 8,698	$ (17,948)	$ 27,771
				DII	$ 39,250	$ -	$ 980	$ 40,230	$ -	$ -	$ 39,184	$ 677	$ 370

As noted earlier, the Total Program Construction Cost for all 39 installations was $8,990,767. The most expensive BMP installation was the EDB constructed at I-15/SR78 (WQ ID No. 111102) at a total cost of $847,712. The least expensive installation was the DII-SG constructed at the Rosemead Maintenance Station (WQ ID No. 073218a) for $25,177. The WB installations had the greatest average total construction cost of all the BMP types for an average of $708,525. The CDS and DII device types had the lowest average cost at just over $40,000. Note that these cost trends do not take BMP size or effectiveness into consideration.

The following pie chart illustrates the relative costs attributed to each of the five cost categories for the Total Pilot Program Construction Cost for all 39 installations. The Base BMP Cost accounted for the greatest percentage of the overall cost, approximately 43 percent of the total. Site-Specific Costs were the second greatest category, with approximately 34 percent of the total. The total percentage attributed to Pilot-Unique Costs was approximately 22 percent of the total, with Monitoring Cost and Non-Monitoring Cost accounting for 11 percent each. Ancillary Costs accounted for approximately 1 percent of the total. The allocation of total cost to the five cost categories varies greatly by BMP device type and by BMP installation, as shown in the detailed analyses in Section II.D. That is, for some BMP devices or installations, the Base BMP Cost accounts for the greatest percentage of overall cost, whereas for others, Site-Specific Costs or some other cost category may be the greatest factor.

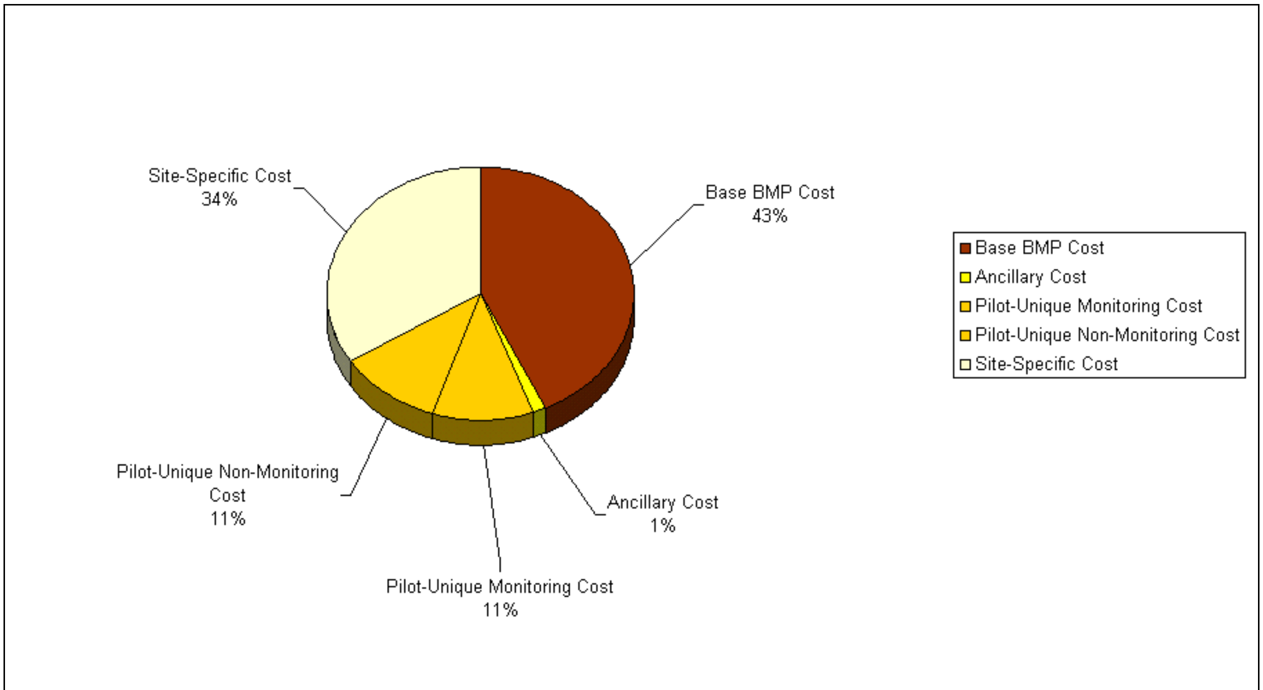


Figure 2 BMP Retrofit Pilot Program Cost Distribution

1. Site-Specific Construction Costs

Table 2, **Site-Specific Cost Breakdown**, shows the detailed breakdown of the Site-Specific Costs for each BMP installation shown in Table 1. As described in Section II.A, these costs are attributable to the specific conditions at the construction site, which may or may not be known at bid time.

The categories identified in Table 2, and the percentage of the Total Pilot Program Construction Cost allocated to each category, are as follows:

BMP No.: As defined in Section II.A.

WQ ID No.: As defined in Section II.A.

BMP Type: As defined in Section II.A.

Site Location: As defined in Section II.A.

Facility Type: As defined in Section II.A.

Inlet/Outlet Drainage Systems: The construction costs associated with the drainage systems necessary to deliver storm water to and away from the BMP device. These costs are independent of the monitoring costs. These costs included placement of pipe, construction of structures to connect to existing drain systems, and associated reconstruction of existing roadway facilities. These costs can vary significantly for the same BMP type depending on the site-specific constraints. Twenty-six sites incurred additional costs attributable to drainage system construction in the Pilot Program. The cost for this item is $760,557, or approximately 8 percent of the total Pilot Program construction costs.

Access Roads (Vector Control/ Maintenance): The construction costs associated with permanent access roads to facilitate BMP device vector control and maintenance requirements. These costs included placement of aggregate base, asphalt concrete pavement, and some Portland cement concrete (PCC) ramps. These costs can vary significantly for the same BMP type depending on the site-specific constraints. Nine sites incurred additional costs attributable to access road construction in the Pilot Program. The cost for this item is $225,340, or approximately 3 percent of the total Pilot Program construction costs.

Site Clearing, Grubbing and Removals: The construction costs associated with site preparation and removals before construction of the BMP device could begin. These costs included clearing and grubbing of existing vegetation; and removal of existing pavement, drainage systems, and structures necessary to construct the BMP device. These items of work are generally known at the time of bidding a project, unlike removal of unsuitable material or utility conflicts. These costs can vary significantly for the same BMP type depending on the site-specific constraints. Thirty sites incurred additional costs attributable to site clearing and removals in the Pilot Program. The cost for this item is $366,466, or approximately 4 percent of the total Pilot Program construction costs.

Utility Conflicts:	The construction costs for relocation, repair, or replacement of existing public utilities. Fifteen sites incurred additional construction costs attributable to utility conflicts in the Pilot Program. The cost for this item is $76,547, or approximately 1 percent of the total Pilot Program construction costs.
Environmental Mitigation:	The construction costs associated with the mitigation of environmentally sensitive areas and related permits. These costs include additional concrete work necessary to protect trees. One site incurred additional construction costs attributable to environmental mitigation in the Pilot Program. The cost for this item is $6,071, or less than 1 percent of the total Pilot Program construction costs.
Dewatering:	The construction costs associated with the removal of local groundwater. One site incurred additional construction costs attributable to dewatering in the Pilot Program. The cost for this item is $4,312, or less than 1 percent of the total Pilot Program construction costs.
Buried Objects:	The construction costs associated with the removal of buried objects, man-made and otherwise, or other unknown unsuitable materials. These costs included excavation and disposal of silt, buried trash, broken asphalt, buried concrete vaults, broken reinforced concrete, and the relocation of large buried boulders. Ten sites incurred additional construction costs attributable to buried objects in the Pilot Program. The cost for this item is $506,647, or approximately 6 percent of the total Pilot Program construction costs.
Safety/Security:	The construction costs associated with the safety (public and traffic) in and around the BMP installation and/or security (from vandals) of the BMP device. These costs included the placement of fences, access gates, and metal beam guardrail (MBGR). Twenty sites incurred additional construction costs attributable to safety and security concerns in the Pilot Program. The cost for this item is $138,240, or approximately 2 percent of the total Pilot Program construction costs.
Required Site-Specific Cost:	The site-specific costs that are required to complete construction of the BMP device regardless of the contract process used to construct the BMP device.
Traffic Control:	The costs associated with temporary signage and traffic controls at the construction access points for worker and public safety. These costs included temporary placement of construction area signs, safety barriers and associated features, flagging costs, and road or shoulder closures. Eighteen sites incurred additional construction costs attributable to traffic control in the Pilot Program. The cost for this item is $342,568, or approximately 4 percent of the total Pilot Program construction costs.
Limited Space:	The construction costs associated with conditions that required construction in physically limited space. These costs were for shoring or repair of existing pavement or structures damaged by pile driving associated with the shoring. Eleven sites incurred additional construction costs attributable to space limitations in the Pilot Program. The cost for this item is $293,775, or approximately 3 percent of the total Pilot Program construction costs.

Limited Head: The construction costs associated with the correcting of permanent drainage problems. Alterations to drainage facilities were necessary because of uneven terrain and right-of-way restrictions. These costs included the purchase of pumps or installation of additional facilities to ensure proper drainage of BMPs where the existing drainage system provided limited head and precluded drainage by gravity. Eight sites incurred additional construction costs attributable to limited head in the Pilot Program. The cost for this item is $108,225, or approximately 1 percent of the total Pilot Program construction costs.

Facility Restoration: The construction costs associated with relocating and/or restoring existing facilities. These costs included construction of storage bins, drainage systems, minor concrete structures, and landscaping to restore existing facilities removed for BMP device construction. Nineteen sites incurred additional construction costs attributable to facility restoration in the Pilot Program. The cost for this item is $207,088, or approximately 2 percent of the total Pilot Program construction costs.

Miscellaneous Other Impacts: The construction costs associated with miscellaneous other impacts. The costs for this category included items of work that were not applicable to the other categories of site-specific cost categories. Examples of miscellaneous site-specific costs are as follows:

- Credits for materials on hand
- Various added and deleted items of work
- Credit from the manufacture of a faulty drainage gate

Seven sites incurred additional construction costs attributable to miscellaneous other impacts in the Pilot Program. The cost for this item is $4,988, or less than 1 percent of the total Pilot Program construction costs.

Retrofit Site-Specific Cost: The site-specific costs that are required to complete construction of the BMP device if the contract process used to construct the BMP device is a retrofit of an existing facility.

Total Site-Specific Cost: The total cost associated with site-specific conditions during construction. It is anticipated that some or all of these factors will impact the cost of constructing BMP devices at other locations. The nature and extent to which costs are impacted will depend on the site and the process (retrofit only, as part of redevelopment, new construction, etc.) used to construct the BMP device.

Percent of Program Total Site-Specific Cost: The site-specific cost associated with each pilot BMP installation as a percentage of the total site-specific costs for the entire Caltrans Retrofit BMP Pilot Program.

Percent of Total Pilot Program Construction: The site-specific costs associated with each BMP installation as a percentage of the total Pilot Program construction cost for the BMP.

The Total Site-Specific Cost for all 39 installations was $3,040,827. Required Site-Specific Costs accounted for $2,084,181, or 69 percent, of this total

Cost: Site-Specific Costs accounted for $2,084,181, or 69 percent, of this total. Retrofit Site-Specific Costs accounted for $956,646, or 31 percent, of the total. Of the Required Site-Specific Costs, Inlet/Outlet Drainage Systems was the largest item, with a cost of $760,557. For Retrofit Site-Specific Costs, Traffic Control was the largest item, with a cost of $342,568. The installation with the greatest Total Site-Specific Cost was the EDB constructed at I-15/SR78 (WQ ID No. 111102) with a cost of $497,514. Eight of the 39 installations incurred no site-specific costs.

The WB installations had the greatest average Total Site Specific Cost of all the BMP types with an average cost of $309,403. The CDS installation had the lowest average total Site-Specific Cost, with $23,860.

TABLE 2 - SITE-SPECIFIC COST BREAKDOWN

BMP No.	WQ ID No.	BMP Type	Site Location	Facility Type	Inlet/Outlet Drainage Systems	Access Roads (Vector Control/Maintenance)	Site Clearing, Grubbing and Removals	Utility Conflicts	Environmental Mitigation	Dewatering	Buried Objects	Safety/Security	Required Site-Specific Cost	Traffic Control	Limited Space	Limited Head	Facility Restoration	Miscellaneous Other Impacts	Retrofit Site-Specific Cost	Total Site-Specific Cost	Percent of Program Total Site-Specific Cost	Percent of Total Pilot Program Construction Cost
					F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U		
													=F+G+H+I+ J+K+L+M						=O+P+Q+ R+S	=N+T		
					Site-Specific Construction Costs																	
San Diego Area, District 11																						
1	111105	EDB	I-5/Manchester (east)	Highway	127,146	17,798	8,328	-	-	-	1,293	1,255	$ 155,819	30,626	-	-	22,530	(1,997)	51,158	$ 206,978	7%	56%
2	111101	EDB	I-5/SR 56	Highway	31,195	23,115	13,672	-	-	-	-	3,943	$ 71,925	1,606	-	-	3,922	(49)	5,479	$ 77,404	3%	48%
3	111102	EDB	I-15/SR 78	Highway	73,776	25,574	15,791	-	-	-	366,641	998	$ 482,780	14,734	-	-	-	-	14,734	$ 497,514	16%	59%
4	111103	IB	I-5/La Costa (west)	Highway	117,525	6,634	11,498	-	-	-	26,932	2,367	$ 164,957	29,490	-	-	-	(81)	29,409	$ 194,365	6%	71%
5	111104	WB	I-5/La Costa (east)	Highway	59,415	92,299	70,890	2,016	-	-	-	11,110	$ 235,730	59,496	-	-	14,177	-	73,673	$ 309,403	10%	44%
6	112201	MFSTF	Kearny Mesa Maint. Station	Maint Station	25,642	-	11,323	2,001	-	4,312	13,751	-	$ 57,029	-	-	-	-	-	-	$ 57,029	2%	18%
7	112202	MFSD	Escondido Maint. Station	Maint Station	38,935	-	17,326	6,539	-	-	-	-	$ 62,800	-	-	-	576	-	576	$ 63,376	2%	14%
8	112203	MFSA	La Costa Park & Ride	Park & Ride	32,120	-	7,015	-	-	-	31,930	13,724	$ 84,789	-	7,066	-	-	-	7,066	$ 91,855	3%	38%
9	112204	MFSA	SR 78/I-5 Park & Ride	Park & Ride	38,457	2,050	6,653	7,943	-	-	-	13,984	$ 69,087	26,090	7,068	-	8,887	-	42,045	$ 111,132	4%	50%
10	112205	BSW	SR 78/Melrose Dr	Highway	9,993	-	6,536	-	-	-	1,793	-	$ 18,322	24,798	-	-	2,092	-	26,890	$ 45,212	1%	32%
11	112206	BSW	I-5/Palomar Airport Rd	Highway	25,022	-	-	5,000	6,071	-	-	735	$ 36,828	6,659	-	-	-	(1,919)	4,740	$ 41,568	1%	30%
12	112207a	BSTRP	Carlsbad Maint. Station (west)	Maint Station	11,064	-	5,401	-	-	-	22,501	-	$ 38,966	-	-	-	4,486	-	4,486	$ 43,451	1%	49%
13	112207b	IT/STRP	Carlsbad Maint. Station (east)	Maint Station	9,648	-	11,793	3,334	-	-	22,501	-	$ 47,277	-	-	-	11,637	-	11,637	$ 58,914	2%	41%
Los Angeles Area, District 07																						
14	073211a	BSTRP	Altadena Maint. Station	Maint Station	11,133	-	13,163	-	-	-	-	9,352	$ 33,648	-	19,729	-	20,573	2,449	42,751	$ 76,399	3%	52%
15	073211b	IT/STRP	Altadena Maint. Station	Maint Station	20,484	-	12,096	605	-	-	-	9,352	$ 42,537	-	76,156	-	38,112	2,449	116,717	$ 159,255	5%	54%
16	073216a	DII-SG	Foothill Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
17	073216b	DII-FF	Foothill Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
18	073217a	DII-SG	Las Flores Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
19	073217b	DII-FF	Las Flores Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
20	073218a	DII-SG	Rosemead Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
21	073218b	DIIFF	Rosemead Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
22	073222a	BSTRP	I-605/SR 91	Highway	-	-	2,609	8,273	-	-	-	-	$ 10,883	18,411	-	-	-	4,136	22,547	$ 33,429	1%	21%
23	073222b	BSW	I-605/SR 91	Highway	-	-	2,609	-	-	-	-	-	$ 2,609	13,114	-	-	-	-	13,114	$ 15,723	1%	24%
24	073223	BSW	Cerritos Maint. Station	Maint Station	-	-	7,234	-	-	-	-	-	$ 7,234	1,779	-	3,795	-	-	5,574	$ 12,808	0%	21%
25	073224	BSW	I-5/I-605	Highway	-	-	2,016	403	-	-	-	-	$ 2,419	26,552	-	-	-	-	26,552	$ 28,972	1%	29%
26	073225	BSW	I-605/Del Amo Ave	Highway	-	-	2,372	4,197	-	-	-	-	$ 6,569	19,272	-	-	-	-	19,272	$ 25,841	1%	20%
27	073102	CDS	I-210/Orcas Ave	Highway	4,600	-	8,102	-	-	-	-	7,350	$ 20,052	-	-	-	1,258	-	1,258	$ 21,310	1%	54%
28	073103	CDS	I-210/Fillmore Ave	Highway	5,030	-	3,890	-	-	-	-	7,240	$ 16,160	-	-	-	10,250	-	10,250	$ 26,410	1%	59%
29	073101	IB	I-605/SR 91	Highway	12,797	25,541	44,615	1,178	-	-	862	15,110	$ 100,102	36,604	-	1,350	10,741	-	48,695	$ 148,797	5%	55%
30	074101	EDB	I-5/I-605 Intersection	Highway	25,083	24,080	3,250	-	-	-	-	11,204	$ 63,617	13,250	1,050	-	-	-	14,300	$ 77,917	3%	46%
31	074102	EDB	I-605/SR 91 Intersection	Highway	24,390	8,250	3,250	-	-	-	-	14,285	$ 50,175	13,250	1,050	-	-	-	14,300	$ 64,475	2%	58%
32	074201	OWS	Alameda Maint. Station	Maint Station	22,439	-	1,719	-	-	-	-	-	$ 24,158	-	-	5,604	2,613	-	8,216	$ 32,375	1%	18%
33	074202	MFSA	Eastern Regional Maint. Sta.	Highway	1,196	-	3,818	18,394	-	-	-	2,624	$ 26,032	-	34,905	22,525	983	-	58,413	$ 84,445	3%	24%
34	074203	MFSA	Foothill Maint. Station	Maint Station	2,412	-	64,887	-	-	-	-	2,919	$ 70,218	5,338	36,813	12,576	47,862	-	102,589	$ 172,806	6%	36%
35	074204	MFSA	Termination Park & Ride	Park & Ride	6,401	-	1,338	11,889	-	-	-	6,403	$ 26,031	-	45,831	19,926	1,450	-	67,206	$ 93,237	3%	20%
36	074103	MFSA	Paxton Park & Ride	Park & Ride	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
37	074206	MCTT	Via Verde Park & Ride	Park & Ride	11,776	-	1,406	415	-	-	18,443	1,453	$ 33,492	1,501	28,249	19,715	2,214	-	51,680	$ 85,172	3%	22%
38	074104	MCTT	Metro Maint. Station	Maint Station	-	-	-	-	-	-	-	-	$ -	-	-	-	-	-	-	$ -	0%	0%
39	074208	MCTT	Lakewood Park & Ride	Park & Ride	12,878	-	1,864	4,360	-	-	-	2,832	$ 21,934	-	35,859	22,735	2,727	-	61,321	$ 83,255	3%	18%
			Pilot Program Total		$ 760,557	$ 225,340	$ 366,466	$ 76,547	$ 6,071	$ 4,312	$ 506,647	$ 138,240	$ 2,084,181	$ 342,568	$ 293,775	$ 108,225	$ 207,088	$ 4,988	$ 956,646	$ 3,040,827	100%	34%
			% Total Site-Specific Cost		25%	7%	12%	3%	0%	0%	17%	5%	69%	11%	10%	4%	7%	0%	31%	100%		
			% Total Pilot Program Const. Cost		8%	3%	4%	1%	0%	0%	6%	2%	23%	4%	3%	1%	2%	0%	11%	34%		
			Average Cost by Facility Type =	All	$ 19,501	$ 5,778	$ 9,397	$ 1,963	$ 156	$ 111	$ 12,991	$ 3,545	$ 53,441	$ 8,784	$ 7,533	$ 2,775	$ 5,310	$ 128	$ 24,529	$ 77,970		
				Highway	$ 30,422	$ 13,135	$ 11,956	$ 2,321	$ 357	$ -	$ 23,384	$ 4,601	$ 86,175	$ 18,109	$ 2,177	$ 1,404	$ 3,880	$ 5	$ 25,575	$ 111,751		
				Maint Station	$ 8,860	$ -	$ 9,059	$ 780	$ -	$ 270	$ 3,672	$ 1,351	$ 23,992	$ 445	$ 8,294	$ 1,373	$ 7,866	$ 306	$ 18,284	$ 42,276		
				Park & Ride	$ 16,939	$ 342	$ 3,046	$ 4,101	$ -	$ -	$ 8,396	$ 6,399	$ 39,222	$ 4,599	$ 20,679	$ 10,396	$ 2,546	$ -	$ 38,220	$ 77,442		
			Average Cost by BMP Type =	EDB	$ 56,318	$ 19,763	$ 8,858	$ -	$ -	$ -	$ 73,587	$ 6,337	$ 164,863	$ 14,693	$ 420	$ -	$ 5,290	$ (409)	$ 19,994	$ 184,858		
				IB	$ 65,161	$ 16,087	$ 28,057	$ 589	$ -	$ -	$ 13,897	$ 8,739	$ 132,529	$ 33,047	$ -	$ 675	$ 5,371	$ (41)	$ 39,052	$ 171,581		
				WB	$ 59,415	$ 92,299	$ 70,890	$ 2,016	$ -	$ -	$ -	$ 11,110	$ 235,730	$ 59,496	$ -	$ -	$ 14,177	$ -	$ 73,673	$ 309,403		
				EDB, IB, WB	$ 58,916	$ 27,911	$ 21,412	$ 399	$ -	$ -	$ 49,466	$ 7,534	$ 165,638	$ 24,882	$ 263	$ 169	$ 6,421	$ (266)	$ 31,468	$ 197,107		
				MFSTF	$ 25,642	$ -	$ 11,323	$ 2,001	$ -	$ 4,312	$ 13,751	$ -	$ 57,029	$ -	$ -	$ -	$ -	$ -	$ -	$ 57,029		
				MFSD	$ 38,935	$ -	$ 17,326	$ 6,539	$ -	$ -	$ -	$ -	$ 62,800	$ -	$ -	$ -	$ 576	$ -	$ 576	$ 63,376		
				MFSA	$ 13,431	$ 342	$ 13,952	$ 6,371	$ -	$ -	$ 5,322	$ 6,609	$ 46,026	$ 5,238	$ 21,947	$ 9,171	$ 9,864	$ -	$ 46,220	$ 92,246		
				MCTT	$ 8,218	$ -	$ 1,090	$ 1,592	$ -	$ -	$ 6,148	$ 1,428	$ 18,476	$ 500	$ 21,369	$ 14,150	$ 1,647	$ -	$ 37,667	$ 56,142		
				MF STF,SD,SA,TT	$ 15,438	$ 186	$ 10,512	$ 4,686	$ -	$ 392	$ 5,829	$ 3,994	$ 41,038	$ 2,994	$ 17,799	$ 8,862	$ 5,882	$ -	$ 35,536	$ 76,574		
				BSW	$ 5,836	$ -	$ 3,461	$ 1,600	$ 1,012	$ -	$ 299	$ 123	$ 12,330	$ 15,362	$ -	$ 633	$ 349	$ (320)	$ 16,024	$ 28,354		
				BSTRP	$ 7,399	$ -	$ 7,058	$ 2,758	$ -	$ -	$ 7,500	$ 3,117	$ 27,832	$ 6,137	$ 6,576	$ -	$ 8,353	$ 2,195	$ 23,261	$ 51,093		
				BSW, BSTRP	$ 6,357	$ -	$ 4,660	$ 1,986	$ 675	$ -	$ 2,699	$ 1,121	$ 17,498	$ 12,287	$ 2,192	$ 422	$ 3,017	$ 518	$ 18,436	$ 35,934		
				IT/STRP	$ 15,066	$ -	$ 11,945	$ 1,969	$ -	$ -	$ 11,251	$ 4,676	$ 44,907	$ -	$ 38,078	$ -	$ 24,875	$ 1,224	$ 64,177	$ 109,084		
				OWS	$ 22,439	$ -	$ 1,719	$ -	$ -	$ -	$ -	$ -	$ 24,158	$ -	$ -	$ 5,604	$ 2,613	$ -	$ 8,216	$ 32,375		
				CDS	$ 4,815	$ -	$ 5,996	$ -	$ -	$ -	$ -	$ 7,295	$ 18,106	$ -	$ -	$ -	$ 5,754	$ -	$ 5,754	$ 23,860		
				DII	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		

2. Ancillary Construction Costs

Table 3, **Ancillary Cost Breakdown**, summarizes Pilot Program ancillary construction costs. As described in Section II.A, these costs are attributable to maintenance, repairs, or upgrades to the existing facilities that are not necessarily required for the construction of the particular BMP device.

The categories identified in Table 3, and the percentage of the Total Pilot Program Construction Cost allocated to each, are as follows:

BMP No.: As defined in Section II.A.

WQ ID No.: As defined in Section II.A.

BMP Type: As defined in Section II.A.

Site Location: As defined in Section II.A.

Facility Type: As defined in Section II.A.

Clear Blocked Storm Drains: The construction costs associated with the clearing and cleaning of blocked storm drains. These costs include extending an existing drainage system previously buried and removing sediment (hazardous material) from existing drainage systems. Without this work, the particular BMP device would not have functioned properly. These costs should be attributed to the maintenance of the existing drainage system. Three sites incurred additional construction costs attributable to clearing and cleaning of blocked storm drains in the Pilot Program. The deducted cost because of the clearing of blocked storm drains is $35,958, less than 1 percent of the total Pilot Program construction costs.

Traffic Safety: The costs associated with constructing permanent traffic control facilities that were required with or without construction of the BMP. These costs include the installation of MBGR. Three sites incurred additional construction costs attributable to permanent traffic control in the Pilot Program. The deducted cost because of traffic safety is $44,263, less than 1 percent of the total Pilot Program construction costs.

Additional Paving: The construction costs associated with providing additional paving beyond that which was necessary for construction of the BMP. These costs include the additional asphalt concrete pavement placed for parking or storage areas not impacted by construction of the BMP device. Two sites incurred additional construction costs attributable to additional paving in the Pilot Program. The deducted cost because of additional paving is $44,599, less than 1 percent of the total Pilot Program construction costs.

Additional Storage Bins: The costs associated with constructing additional storage bins for an existing facility. These bins were not required for the proper functioning of the BMP device, nor were they to replace bins that were removed for the construction of the BMP device. No sites incurred additional construction costs attributable to additional storage bins in the Pilot Program. The deducted cost due to the construction of additional storage bins is $0, representing zero percent of the

	total Pilot Program construction costs. Storage bins were constructed at the Altadena Maintenance Station pilot site (WQ ID No. 073211) to mitigate for the loss of existing bins to accommodate the construction of the BMP. Since this work was to restore storage capacity, and not to provide additional capacity, this cost was not allocated to this category.
Total Ancillary Cost:	The total ancillary construction costs in the Pilot Program. Although future BMP construction will likely provide opportunities to perform ancillary work, it is not considered appropriate to attribute that cost to the BMP device. Unlike the site-specific construction costs, none of the ancillary construction costs are associated with the final BMP device construction, regardless of the site or the process (retrofit only, as part of redevelopment, new construction, etc.) used to construct the BMP device. Therefore, these costs will be deducted from the Pilot Program construction costs to determine the actual cost of each BMP installation.
Percent of Program Total Ancillary Cost:	The ancillary cost associated with each BMP installation as a percentage of the total ancillary costs for the entire Caltrans Retrofit BMP Pilot Program.
Percent of Total Pilot Program Construction Cost:	The ancillary costs associated with each BMP installation as a percentage of the total Pilot Program Construction Cost for the BMP installation.

The total deducted cost for ancillary construction represents approximately 1.4 percent of the total Pilot Program construction costs.
The Total Ancillary Cost for all 39 installations was $124,820. Traffic Safety and Additional Paving were the largest items, with costs of approximately $45,000 each. No cost was attributed to Additional Storage Bins. The installation with the greatest Ancillary Cost was the IB constructed at I-605/SR91 (WQ ID No. 073101) with a cost of $33,347. Thirty-three of the 39 installations incurred no Ancillary Costs.

The WB installations had the greatest average Ancillary Cost of all the BMP types with $19,359. Eight of the 13 BMP device types incurred no Ancillary costs.

TABLE 3 - ANCILLARY COST BREAKDOWN

BMP No.	WQ ID No.	BMP Type	Site Location	Facility Type	D	E	F	G	H		
									=D+E+F+G		
					Ancillary Construction Costs						
					Clear Blocked Storm Drains	Traffic Saftey	Additional Paving	Additional Storage Bins	Total Ancillary Cost	Percent of Program Total Ancillary Cost	Percent of Total Pilot Program Construction Cost
San Diego Area, District 11											
1	111105	EDB	I-5/Manchester (east)	Highway	-	-	-	-	$ -	0%	0.0%
2	111101	EDB	I-5/SR 56	Highway	-	-	-	-	$ -	0%	0.0%
3	111102	EDB	I-15/SR 78	Highway	-	-	-	-	$ -	0%	0.0%
4	111103	IB	I-5/La Costa (west)	Highway	-	-	-	-	$ -	0%	0.0%
5	111104	WB	I-5/La Costa (east)	Highway	13,130	6,229	-	-	$ 19,359	16%	2.7%
6	112201	MFSTF	Kearny Mesa Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
7	112202	MFSD	Escondido Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
8	112203	MFSA	La Costa Park & Ride	Park & Ride	-	-	-	-	$ -	0%	0.0%
9	112204	MFSA	SR 78/I-5 Park & Ride	Park & Ride	-	-	-	-	$ -	0%	0.0%
10	112205	BSW	SR 78/Melrose Dr	Highway	3,881	-	-	-	$ 3,881	3%	2.7%
11	112206	BSW	I-5/Palomar Airport Rd	Highway	-	23,634	-	-	$ 23,634	19%	17.2%
12	112207a	BSTRP	Carlsbad Maint. Station (west)	Maint Station	-	-	22,299	-	$ 22,299	18%	25.0%
13	112207b	IT/STRP	Carlsbad Maint. Station (east)	Maint Station	-	-	22,299	-	$ 22,299	18%	15.7%
Los Angeles Area, District 07											
14	073211a	BSTRP	Altadena Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
15	073211b	IT/STRP	Altadena Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
16	073216a	DII-SG	Foothill Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
17	073216b	DII-FF	Foothill Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
18	073217a	DII-SG	Las Flores Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
19	073217b	DII-FF	Las Flores Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
20	073218a	DII-SG	Rosemead Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
21	073218b	DIIFF	Rosemead Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
22	073222a	BSTRP	I-605/SR 91	Highway	-	-	-	-	$ -	0%	0.0%
23	073222b	BSW	I-605/SR 91	Highway	-	-	-	-	$ -	0%	0.0%
24	073223	BSW	Cerritos Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
25	073224	BSW	I-5/I-605	Highway	-	-	-	-	$ -	0%	0.0%
26	073225	BSW	I-605/Del Amo Ave	Highway	-	-	-	-	$ -	0%	0.0%
27	073102	CDS	I-210/Orcas Ave	Highway	-	-	-	-	$ -	0%	0.0%
28	073103	CDS	I-210/Fillmore Ave	Highway	-	-	-	-	$ -	0%	0.0%
29	073101	IB	I-605/SR 91	Highway	18,947	14,400	-	-	$ 33,347	27%	12.4%
30	074101	EDB	I-5/I-605 Intersection	Highway	-	-	-	-	$ -	0%	0.0%
31	074102	EDB	I-605/SR 91 Intersection	Highway	-	-	-	-	$ -	0%	0.0%
32	074201	OWS	Alameda Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
33	074202	MFSA	Eastern Regional Maint. Sta.	Highway	-	-	-	-	$ -	0%	0.0%
34	074203	MFSA	Foothill Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
35	074204	MFSA	Termination Park & Ride	Park & Ride	-	-	-	-	$ -	0%	0.0%
36	074103	MFSA	Paxton Park & Ride	Park & Ride	-	-	-	-	$ -	0%	0.0%
37	074206	MCTT	Via Verde Park & Ride	Park & Ride	-	-	-	-	$ -	0%	0.0%
38	074104	MCTT	Metro Maint. Station	Maint Station	-	-	-	-	$ -	0%	0.0%
39	074208	MCTT	Lakewood Park & Ride	Park & Ride	-	-	-	-	$ -	0%	0.0%
			Pilot Program Total		$ 35,958	$ 44,263	$ 44,599	$ -	$ 124,820	100%	1.4%
			% Total Ancillary Cost		29%	35%	36%	0%	100%		
			% Total Pilot Program Const. Cost		0.4%	0.5%	0.5%	0.0%	1.4%		
			Average Cost by Facility Type =	All	$ 922	$ 1,135	$ 1,144	$ -	$ 3,201		
				Highway	$ 2,115	$ 2,604	$ -	$ -	$ 4,719		
				Maint Station	$ -	$ -	$ 2,787	$ -	$ 2,787		
				Park & Ride	$ -	$ -	$ -	$ -	$ -		
			Average Cost by BMP Type =	EDB	$ -	$ -	$ -	$ -	$ -		
				IB	$ 9,474	$ 7,200	$ -	$ -	$ 16,674		
				WB	$ 13,130	$ 6,229	$ -	$ -	$ 19,359		
				EDB, IB, WB	$ 4,010	$ 2,579	$ -	$ -	$ 6,588		
				MFSTF	$ -	$ -	$ -	$ -	$ -		
				MFSD	$ -	$ -	$ -	$ -	$ -		
				MFSA	$ -	$ -	$ -	$ -	$ -		
				MCTT	$ -	$ -	$ -	$ -	$ -		
				MF STF,SD,SA,TT	$ -	$ -	$ -	$ -	$ -		
				BSW	$ 647	$ 3,939	$ -	$ -	$ 4,586		
				BSTRP	$ -	$ -	$ 7,433	$ -	$ 7,433		
				BSW, BSTRP	$ 431	$ 2,626	$ 2,478	$ -	$ 5,535		
				IT/STRP	$ -	$ -	$ 11,150	$ -	$ 11,150		
				OWS	$ -	$ -	$ -	$ -	$ -		
				CDS	$ -	$ -	$ -	$ -	$ -		
				DII	$ -	$ -	$ -	$ -	$ -		

3. Pilot-Unique Construction Costs

Table 4, **Pilot-Unique Cost Breakdown**, summarizes construction costs associated with the unique requirements of the Pilot Program. Unique construction costs associated with the Pilot Program are further broken down into two cost categories: Monitoring Costs and Non-Monitoring Costs.

The categories identified in Table 4, and the percentage of the Total Pilot Program Construction Cost allocated to each, is as follows:

BMP No.: As defined in Section II.A.

WQ ID No.: As defined in Section II.A.

BMP Type: As defined in Section II.A.

Site Location: As defined in Section II.A.

Facility Type: As defined in Section II.A.

Monitoring Construction Cost

Monitoring Construction Costs are directly attributable to the construction of separate facilities to directly monitor the pollutant removal effectiveness of the BMP or to ensure that effectiveness results were not skewed.

Sampling Equipment: The construction costs associated with constructing sampling and monitoring equipment and facilities. These costs include flumes, concrete equipment pads, flume approach sections, monitoring wells, and lysimeters. Twenty-one sites incurred additional construction costs attributable to sampling equipment in the Pilot Program. The deducted cost because of sampling equipment is $71,827, approximately 1 percent of the total Pilot Program construction costs.

All BMP devices were measured for effectiveness, and, therefore, should have a related sampling equipment cost. However, in some cases, cost data provided only a lump sum for Associated Structures. In these cases, sampling equipment costs are included in that cost category.

Associated Structures: The construction costs associated with the construction of structures required to convey water to sampling and monitoring points. These costs include constructing diversion boxes, junction boxes, manholes, and drainage facilities specifically for monitoring purposes, or to direct non-monitored flows around the monitoring equipment and the BMP device. Thirty-six sites incurred additional construction costs attributable to associated structures equipment in the Pilot Program The deducted cost due to associated structures is $522,358, approximately 6 percent of the total Pilot Program construction costs.

Power Supply: The construction costs associated with constructing facilities to supply power for monitoring. These costs include installing conduit, pull boxes, outlet receptacles, and performing electrical panel upgrades. Twenty-three sites incurred additional construction costs attributable to power supply in the Pilot

Program. The deducted cost for supplying power is $207,370, approximately 2 percent of the total Pilot Program construction costs.

Higher Cost BMP Components: The construction costs associated with providing specialized materials because of monitoring requirements. These costs include providing drainage pipe with watertight joints, and stainless steel items, such as manholes and drainage gates. Ten sites incurred additional construction costs attributable to higher cost BMP components in the Pilot Program. The deducted cost because of the higher cost of components is $82,748, approximately 1 percent of the total Pilot Program construction costs.

Protection/Security Facilities: The construction costs associated with providing facilities solely to protect sampling and monitoring equipment from damage, vandalism, and theft. These costs include fencing, access gates, and MBGR. Sixteen sites incurred additional construction costs attributable to protection or security of monitoring facilities in the Pilot Program. The deducted cost because of the construction of protection and security facilities is $52,170, approximately 1 percent of the total Pilot Program construction costs.

Site Access: The construction costs associated with providing access to sampling and monitoring equipment. These costs include aggregate base and asphalt concrete paving. Two sites incurred additional construction costs attributable to site monitoring access in the Pilot Program. The deducted cost because of site access is $17,542, less than 1 percent of the total Pilot Program construction costs.

Total Monitoring Cost: The sum of construction costs related to the monitoring requirements of the Pilot Program. Unlike the site-specific construction costs, none of the pilot-unique monitoring costs are expected to be applicable to final BMP device construction regardless of the site or the process (retrofit only, as part of redevelopment, new construction, etc.) used to construct the BMP device. Therefore, these costs will be deducted from the Pilot Program construction costs to determine the actual cost of each BMP installation. The total deducted cost for pilot-unique monitoring represents approximately 11 percent of the total Pilot Program construction costs.

Non-Monitoring Construction Cost

Non-monitoring costs are specific to the Pilot Program, but are unrelated to monitoring requirements. These costs are associated with the accelerated implementation of the program, the contract packaging of the BMP devices, the contracting process, and the lack of designer or contractor familiarity and/or experience with the various BMP devices.

Requirements & Artificialities

Requirements and artificiality costs are attributable to the time constraints stipulated by the Consent Decrees and/or limiting BMP site selection to the Caltrans right-of-way. This category is further segregated into the following cost categories:

Accelerated Time of Completion: The construction costs associated with imposed construction deadlines of the Pilot Program. These costs include use of more costly materials (sod versus seed), construction acceleration costs (premium time), and adjustments to contract bonding requirements. The negative costs represent savings realized because of lower bonding requirements associated with the acceleration of construction.

Eighteen sites incurred additional construction costs attributable to the accelerated time of completion in the Pilot Program. The added cost attributed to this item was $184,517, approximately 2 percent of the Total Pilot Program Construction Cost.

Site Selection Artificialities: The construction costs associated with site selection constraints and size of BMP devices. The BMP devices selected may not always be appropriate for the site. These costs included shoring costs attributable to sand filters and multi-chambered treatment trains constructed in Los Angeles. In the Pilot Program, no sites incurred adjustments to construction costs attributable to site selection artificialities.

Sharing of Costs: The construction costs or savings associated with construction of the BMP device as part of a process other than retrofitting (redevelopment, new construction, etc.). These costs could be attributed to other items of work, and not specifically to the BMP device. Construction costs, such as, mobilization, clearing and grubbing, earthwork, and drainage systems, may be shared when BMP devices are installed in conjunction with new construction or redevelopment of a facility. In the Pilot Program, no sites incurred adjustments to construction costs attributable to sharing of costs.

Scoping/Site Limitations: The construction costs associated with limiting BMP device construction to the Caltrans right-of-way. Partnering with other local agencies may provide efficiencies of scale and reduce overall cost. In the Pilot Program, no sites incurred adjustments to construction costs attributable to scoping/site limitations.

Contract Method

Contract method defines the process used to select contractors for the BMP Pilot Program versus the standard Caltrans bidding process. The bid process for the Pilot Program consisted of three types of bid packages: the standard Caltrans competitive bid (PS&E), contract procurement (competitive bid through consultants), and CCO. The PS&E process includes a mass advertisement of the contract, a deadline for the submittal of bids, and awarding of the contract to the lowest bidder. This bidding process best ensures a competitive market price for the work of the contract.

Lack of Competitive Bid: The estimated construction costs associated with having a limited number of bidding contractors or having a BMP device constructed by CCO rather than competitive bid. For the Pilot Program, no costs were allocated to Lack of Competitive Bid due to the unique requirements of the Pilot Program. Of the 39 installed BMP devices, 11 were awarded through PS&E bids, 26 were awarded on a Procurement basis, and 2 were awarded as CCOs. The number of bidders varied between 2 and 11, with an average of 3 bids received for each package.

With the exception of I-5/Manchester (BMP No. 1), which was constructed as a CCO to an ongoing project, the bidding procedures encouraged competitive bidding as much as possible. I-5/Palomar Airport Road (BMP No. 11) was also constructed as a CCO, but was part of a procurement bid package.

From the number and the dollar value of bids received, it appears that bidding was moderately competitive for the difficulty of the work, experience of contractors, and the given economic environment.

Larger contractors with the resources to bid on the larger projects showed moderate to low interest with two to four bids received. Smaller contractors (contracts under $150,000) showed average to high interest with up to eleven bids received.

Experience of Designers & Contractors

This category identifies factors that impact construction costs attributable to designer and/or contractor lack of familiarity or experience with the BMP devices.

Standard Designs: The construction costs associated with the lack of standardized designs for the components of the BMP devices. Standard components may provide a greater construction efficiency and predictability for contractors. No sites incurred additional construction costs attributable to the lack of standardized designs in the Pilot Program.

Site-Specific Designs The construction costs associated with the unfamiliarity of site-specific BMP design requirements, including the need for proper planning for some BMPs. Additional costs due to site-specific design issues may result from:

- Geotechnical oversights, such as, constructing infiltration basins in areas of high groundwater
- Relocation of BMP devices due to utility conflicts
- Compensation for overhead for the deletion of two BMP devices from the contract
- Construction of safety features strongly recommended by the California Highway Patrol
- Removal and disposal of mulch material
- Import of earthwork material because of unbalanced earthwork quantities

In the Pilot Program, 17 sites incurred additional construction costs attributable to the lack of identifying site-specific design requirements. The cost adjustment due to the unfamiliarity of site-specific designs was $100,764, approximately 1 percent of the total Pilot Program construction costs.

In Table 4, the cost savings of $7,343 for BMP No. 6 (Kearny Mesa Maintenance Station), represented savings from a credit issued by the StormFilter manufacturer. The StormFilter originally supplied did not contain the correct number of cartridges, so the manufacturer supplied the additional cartridges at no additional cost, resulting in a savings of $8,208. In addition, a non-standard pre-treatment vault was originally specified, which was subsequently replaced by a standard vault for an additional cost of $685, resulting in a net savings of $7,343.

Overdesigned Features: The construction costs associated with the construction of non-essential or more costly components of the BMP device. These costs include over-excavation of material and placement of an impervious liner in conjunction with the construction of a wet basin, including a layer of porous material with the construction of one extended detention basin, including a concrete liner for another extended detention basin, and constructing concrete ramps for various extended detention basins.

Four sites incurred additional construction costs attributable to overdesigned features in the Pilot Program. The added cost due to overdesigned features is $157,064, approximately 2 percent of the total Pilot Program construction cost.

Vector Control: This category considers cost adjustments due to unfamiliarity with vector control issues. For the Pilot Program, these costs included the rework of various components to satisfy vector control requirements, including grouting of an energy dissipater, modifying a basin inlet, and rework required for rock slope protection. Eight sites incurred additional construction costs attributable to vector control issues in the Pilot Program. The added cost due to vector control is $14,100, or less than 1 percent of the total Pilot Program construction cost.

Construction Contractor's Experience: This category considers cost adjustments due to the contractor experience bidding on and constructing the BMP devices. For the Pilot Program, both costs and savings were realized due to this item. For contracts with a lump sum bid, the third party team analyzed the work to be done under the contract to determine the allocation of costs to the various cost categories for this study.

In some cases, the analysis indicated that the contractor overbid or underbid the contract. If the analysis indicated that the contractor overbid, the overbid amount was deducted from the Actual Construction Cost of the BMP device to arrive at a more accurate and lower adjusted cost for the BMP device. If the analysis indicated that the contractor underbid, the difference between the bid and the third party engineer's estimated cost was added to the Actual Construction Cost, resulting in a more accurate and higher cost for the BMP device. In these cases, the Adjusted Construction Cost is greater than 100 percent of the Actual Construction Cost.

Twenty-three sites incurred additional construction costs attributable to contractor inexperience in the Pilot Program. The net adjustment for this item for the Pilot Program was an added cost of $549,645, or approximately 6 percent of the Total Pilot Program Construction Cost..

Construction Efficiency

The efficiency of construction operations depends on many factors. Considering all types of construction operations, these factors include the individuals that form the work crews, the equipment used for the particular construction activity, the distances between construction areas, the available area in which to construct, the maneuverability within the construction area, etc. Construction efficiency costs, or inefficiencies, are attributable to the limitations and configurations of the BMP installations in the Pilot Program. This category is further segregated into the following categories:

Quantity of BMPs: This category considers cost adjustments due to the relatively small number of BMPs required for the Pilot Program. Relatively low quantities can increase costs due to inefficient use of equipment and labor, inefficient overhead costs, and inability to take advantage of volume discounts. No sites incurred additional construction costs attributable to the quantity of BMPs in the Pilot Program.

Size of BMPs: This category considers cost adjustments due to any constraints to the size of the BMP devices because of the unique requirements of the Pilot Program. BMP device size affects the per unit cost (the cost of the BMP device per water quality design unit). For example, a larger detention basin costs more to construct, but generally costs less per unit of storm water treated. A smaller device is cheaper to construct, but has a higher cost per unit of treated storm water due to inefficient overhead costs and the inability to obtain volume discounts. No sites incurred additional construction costs attributable to the size of BMP devices in the Pilot Program.

Total Non-Monitoring Cost: The sum of construction costs directly attributable to unique Pilot Program requirements that were not related to BMP device monitoring. The cost adjustments are not dependent on the site or the construction process (retrofit, redevelopment, new construction, etc.) used to construct the BMP. Adjustments to BMP installation costs attributed to pilot-unique non-monitoring costs are addressed in the Section II.C.

Total Pilot-Unique Cost: The sum of additional construction costs related to unique Pilot Program requirements (monitoring and non-monitoring).

Percent of Program Total Pilot-Unique Cost: The unique Pilot Program cost associated with each BMP installation as a percentage of the Total Pilot-Unique Costs for the entire Pilot Program.

Percent of Total Pilot Program Construction Cost: The unique Pilot Program costs associated with each BMP installation as a percentage of the total Pilot Program construction cost for the BMP installation (from Table 1).

TABLE 4 - PILOT-UNIQUE COST BREAKDOWN

BMP No.	WQ ID No.	BMP Type	Site Location	Facility Type	Pilot-Unique Construction Costs: Monitoring Construction Cost: Sampling Equipment	Associated Structures	Power Supply	Higher Cost BMP Components	Protection/Security Facilities	Site Access	Total Monitoring Cost	Non-Monitoring Construction Cost: Requirements & Artificialities: Accelerated Time of Completion	Site Selection Artificialities	Sharing of Costs	Scoping/Site Limitations	Contract Method: Lack of Competetive Bid	Experience of Designers & Contractors: Standard Designs	Site-Specific Designs	Overdesigned Features	Vector Control	Construction Contractor's Experience	Construction Efficiency: Quantity of BMPs	Size of BMPs	Total Non-Monitoring Cost	Total Cost: Total Pilot-Unique Cost	Percent of Program Total Pilot-Unique Cost	Percent of Total Pilot Program Construction Cost
					E	F	G	H	I	J	K	L	M	N	O	Q	R	S	T	U	V	X	Y	Z	AA		
											=E+F+G+H+I+J													=P+Q+W+X+Y	=K+Z		
San Diego Area, District 11																											
1	111105	EDB	I-5/Manchester (east)	Highway	4,452	18,388	-	259	-	-	$ 23,098	5,657	-	-	-	-	-	-	24,303	-	47,642	-	-	$ 77,602	$ 100,700	5%	27%
2	111101	EDB	I-5/SR 56	Highway	3,302	13,762	-	4,951	-	-	$ 22,015	-	-	-	-	-	-	10,082	-	-	-	-	-	$ 10,082	$ 32,097	2%	20%
3	111102	EDB	I-15/SR 78	Highway	2,498	34,255	-	17,655	-	-	$ 54,407	72,450	-	-	-	-	-	3,310	-	842	-	-	-	$ 76,602	$ 131,009	7%	15%
4	111103	IB	I-5/La Costa (west)	Highway	1,202	7,075	-	3,094	-	-	$ 11,371	-	-	-	-	-	-	38,254	-	-	-	-	-	$ 38,254	$ 49,625	3%	18%
5	111104	WB	I-5/La Costa (east)	Highway	5,533	28,044	-	21,561	-	-	$ 55,138	-	-	-	-	-	-	19,633	65,696	-	-	-	-	$ 85,329	$ 140,467	7%	20%
6	112201	MFSTF	Kearny Mesa Maint. Station	Maint Station	1,800	18,362	-	-	-	-	$ 20,162	-	-	-	-	-	-	(7,343)	-	-	-	-	-	$ (7,343)	$ 12,819	1%	4%
7	112202	MFSD	Escondido Maint. Station	Maint Station	1,800	15,874	18,000	17,929	1,874	-	$ 55,477	-	-	-	-	-	-	-	-	-	147,227	-	-	$ 147,227	$ 202,704	10%	45%
8	112203	MFSA	La Costa Park & Ride	Park & Ride	1,900	11,313	260	1,000	-	-	$ 14,473	-	-	-	-	-	-	5,368	-	-	(8,974)	-	-	$ (3,606)	$ 10,866	1%	5%
9	112204	MFSA	SR 78/I-5 Park & Ride	Park & Ride	2,000	11,933	-	-	-	-	$ 13,933	-	-	-	-	-	-	959	-	-	(23,179)	-	-	$ (22,220)	$ (8,287)	0%	-4%
10	112205	BSW	SR 78/Melrose Dr	Highway	3,342	2,800	-	-	3,200	-	$ 9,342	47,123	-	-	-	-	-	549	-	-	-	-	-	$ 47,672	$ 57,014	3%	40%
11	112206	BSW	I-5/Palomar Airport Rd	Highway	-	428	-	-	-	-	$ 428	12,786	-	-	-	-	-	-	-	-	-	-	-	$ 12,786	$ 13,214	1%	10%
12	112207a	BSTRP	Carlsbad Maint. Station (west)	Maint Station	900	282	7,500	-	-	-	$ 8,682	-	-	-	-	-	-	-	-	-	-	-	-	$ -	$ 8,682	0%	10%
13	112207b	IT/STRP	Carlsbad Maint. Station (east)	Maint Station	1,976	13,742	7,500	-	-	-	$ 23,218	-	-	-	-	-	-	347	-	-	-	-	-	$ 347	$ 23,565	1%	17%
Los Angeles Area, District 07																											
14	073211a	BSTRP	Altadena Maint. Station	Maint Station	1,169	20,967	11,267	6,401	249	-	$ 40,052	3,964	-	-	-	-	-	-	-	-	-	-	-	$ 3,964	$ 44,016	2%	30%
15	073211b	IT/STRP	Altadena Maint. Station	Maint Station	1,168	28,083	11,267	6,401	249	-	$ 47,167	4,820	-	-	-	-	-	-	-	-	-	-	-	$ 4,820	$ 51,987	3%	18%
16	073216a	DII-SG	Foothill Maint. Station	Maint Station	-	12,470	15,084	-	-	-	$ 27,555	(86)	-	-	-	-	-	-	-	-	816	-	-	$ 730	$ 28,285	1%	99%
17	073216b	DII-FF	Foothill Maint. Station	Maint Station	-	28,258	15,084	-	712	-	$ 44,054	(137)	-	-	-	-	-	-	-	-	816	-	-	$ 679	$ 44,734	2%	99%
18	073217a	DII-SG	Las Flores Maint. Station	Maint Station	-	25,961	19,442	-	712	-	$ 46,114	(196)	-	-	-	-	-	-	-	-	816	-	-	$ 620	$ 46,734	2%	99%
19	073217b	DII-FF	Las Flores Maint. Station	Maint Station	-	34,787	19,442	-	1,067	-	$ 55,296	(193)	-	-	-	-	-	-	-	-	816	-	-	$ 623	$ 55,918	3%	99%
20	073218a	DII-SG	Rosemead Maint. Station	Maint Station	-	13,250	10,116	-	712	-	$ 24,077	(86)	-	-	-	-	-	-	-	-	816	-	-	$ 730	$ 24,807	1%	99%
21	073218b	DIIFF	Rosemead Maint. Station	Maint Station	-	27,890	10,116	-	-	-	$ 38,006	(137)	-	-	-	-	-	-	-	-	816	-	-	$ 679	$ 38,685	2%	99%
22	073222a	BSTRP	I-605/SR 91	Highway	3,305	55,736	8,302	3,500	762	-	$ 71,604	17,661	-	-	-	-	-	8,952	-	-	(4,792)	-	-	$ 21,820	$ 93,424	5%	59%
23	073222b	BSW	I-605/SR 91	Highway	3,305	10,118	8,302	-	-	-	$ 21,724	6,199	-	-	-	-	-	-	-	2,247	(4,792)	-	-	$ 3,654	$ 25,378	1%	39%
24	073223	BSW	Cerritos Maint. Station	Maint Station	4,600	13,757	8,302	-	-	1,788	$ 28,447	1,348	-	-	-	-	-	-	-	2,247	-	-	-	$ 3,595	$ 32,042	2%	53%
25	073224	BSW	I-5/I-605	Highway	3,414	14,231	5,930	-	-	-	$ 23,575	8,586	-	-	-	-	-	-	-	3,679	12,079	-	-	$ 24,345	$ 47,920	2%	48%
26	073225	BSW	I-605/Del Amo Ave	Highway	10,767	-	14,231	-	16,485	15,754	$ 57,237	4,881	-	-	-	-	-	-	-	3,203	13,133	-	-	$ 21,216	$ 78,453	4%	61%
27	073102	CDS	I-210/Orcas Ave	Highway	6,052	2,000	-	-	-	-	$ 8,052	-	-	-	-	-	-	-	-	-	(16,468)	-	-	$ (16,468)	$ (8,416)	0%	-21%
28	073103	CDS	I-210/Fillmore Ave	Highway	7,343	2,000	-	-	-	-	$ 9,343	-	-	-	-	-	-	-	-	-	(19,428)	-	-	$ (19,428)	$ (10,085)	-1%	-22%
29	073101	IB	I-605/SR 91	Highway	-	150	-	-	-	-	$ 150	-	-	-	-	-	-	2,912	20,865	1,572	1,007	-	-	$ 26,356	$ 26,506	1%	10%
30	074101	EDB	I-5/I-605 Intersection	Highway	-	11,850	-	-	-	-	$ 11,850	-	-	-	-	-	-	-	46,200	155	-	-	-	$ 46,355	$ 58,205	3%	34%
31	074102	EDB	I-605/SR 91 Intersection	Highway	-	19,632	-	-	-	-	$ 19,632	-	-	-	-	-	-	-	-	155	-	-	-	$ 155	$ 19,787	1%	18%
32	074201	OWS	Alameda Maint. Station	Maint Station	-	6,449	4,584	-	5,023	-	$ 16,055	(122)	-	-	-	-	-	5,540	-	-	24,056	-	-	$ 29,473	$ 45,528	2%	25%
33	074202	MFSA	Eastern Regional Maint. Sta.	Highway	-	3,358	3,432	-	4,126	-	$ 10,916	-	-	-	-	-	-	2,025	-	-	79,847	-	-	$ 81,872	$ 92,788	5%	26%
34	074203	MFSA	Foothill Maint. Station	Maint Station	-	3,752	1,295	-	2,535	-	$ 7,582	-	-	-	-	-	-	2,394	-	-	76,677	-	-	$ 79,071	$ 86,653	4%	18%
35	074204	MFSA	Termination Park & Ride	Park & Ride	-	4,926	2,611	-	4,711	-	$ 12,249	-	-	-	-	-	-	2,536	-	-	76,751	-	-	$ 79,287	$ 91,536	5%	19%
36	074103	MFSA	Paxton Park & Ride	Park & Ride	-	-	-	-	-	-	$ -	-	-	-	-	-	-	-	-	-	-	-	-	$ -	$ -	0%	0%
37	074206	MCTT	Via Verde Park & Ride	Park & Ride	-	3,307	2,652	-	4,275	-	$ 10,234	-	-	-	-	-	-	2,399	-	-	72,495	-	-	$ 74,895	$ 85,128	4%	22%
38	074104	MCTT	Metro Maint. Station	Maint Station	-	-	-	-	-	-	$ -	-	-	-	-	-	-	-	-	-	-	-	-	$ -	$ -	0%	0%
39	074208	MCTT	Lakewood Park & Ride	Park & Ride	-	3,169	2,652	-	5,478	-	$ 11,299	-	-	-	-	-	-	2,849	-	-	71,470	-	-	$ 74,319	$ 85,618	4%	18%
			Pilot Program Total		$ 71,827	$ 522,358	$ 207,370	$ 82,748	$ 52,170	$ 17,542	$ 954,015	$ 184,517	$ -	$ -	$ -	$ -	$ -	$ 100,764	$ 157,064	$ 14,100	$ 549,645	$ -	$ -	$ 1,006,090	$ 1,960,105	100%	21.8%
			% Total Pilot-Unique Cost		8%	55%	22%	9%	5%	2%	100%	18%	0%	0%	0%	0%	0%	10%	16%	1%	55%	0%	0%	100%	100%		
			% Total Pilot Program Const. Cost		1%	6%	2%	1%	1%	0%	11%	2%	0%	0%	0%	0%	0%	1%	2%	0%	6%	0%	0%	11%	22%		
			Average Cost by Facility Type =	All	$ 1,842	$ 13,394	$ 5,317	$ 2,122	$ 1,338	$ 450	$ 24,462	$ 4,731	$ -	$ -	$ -	$ -	$ -	$ 2,584	$ 4,027	$ 362	$ 14,093	$ -	$ -	$ 25,797	$ 50,259		
				Highway	$ 3,207	$ 13,166	$ 2,365	$ 3,001	$ 1,445	$ 927	$ 24,111	$ 10,314	$ -	$ -	$ -	$ -	$ -	$ 5,042	$ 9,239	$ 697	$ 6,366	$ -	$ -	$ 31,659	$ 55,770		
				Maint Station	$ 838	$ 16,493	$ 9,937	$ 1,921	$ 821	$ 112	$ 30,122	$ 573	$ -	$ -	$ -	$ -	$ -	$ 59	$ -	$ 140	$ 15,803	$ -	$ -	$ 16,576	$ 46,697		
				Park & Ride	$ 650	$ 5,775	$ 1,363	$ 167	$ 2,411	$ -	$ 10,365	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,352	$ -	$ -	$ 31,427	$ -	$ -	$ 33,779	$ 44,143		
			Average Cost by BMP Type =	EDB	$ 2,050	$ 19,577	$ -	$ 4,573	$ -	$ -	$ 26,201	$ 15,621	$ -	$ -	$ -	$ -	$ -	$ 2,678	$ 14,101	$ 230	$ 9,528	$ -	$ -	$ 42,159	$ 68,360		
				IB	$ 601	$ 3,613	$ -	$ 1,547	$ -	$ -	$ 5,761	$ -	$ -	$ -	$ -	$ -	$ -	$ 20,583	$ 10,433	$ 786	$ 504	$ -	$ -	$ 32,305	$ 38,066		
				WB	$ 5,533	$ 28,044	$ -	$ 21,561	$ -	$ -	$ 55,138	$ -	$ -	$ -	$ -	$ -	$ -	$ 19,633	$ 65,696	$ -	$ -	$ -	$ -	$ 85,329	$ 140,467		
				EDB, IB, WB	$ 2,123	$ 16,644	$ -	$ 5,940	$ -	$ -	$ 24,708	$ 9,763	$ -	$ -	$ -	$ -	$ -	$ 9,274	$ 19,633	$ 340	$ 6,081	$ -	$ -	$ 45,092	$ 69,799		
				MFSTF	$ 1,800	$ 18,362	$ -	$ -	$ -	$ -	$ 20,162	$ -	$ -	$ -	$ -	$ -	$ -	$ (7,343)	$ -	$ -	$ -	$ -	$ -	$ (7,343)	$ 12,819		
				MFSD	$ 1,800	$ 15,874	$ 18,000	$ 17,929	$ 1,874	$ -	$ 55,477	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 147,227	$ -	$ -	$ 147,227	$ 202,704		
				MFSA	$ 650	$ 5,880	$ 1,266	$ 167	$ 1,896	$ -	$ 9,859	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,214	$ -	$ -	$ 33,520	$ -	$ -	$ 35,734	$ 45,593		
				MCTT	$ -	$ 2,159	$ 1,768	$ -	$ 3,251	$ -	$ 7,178	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,749	$ -	$ -	$ 47,989	$ -	$ -	$ 49,738	$ 56,916		
				MF STF,SD,SA,TT	$ 682	$ 6,909	$ 2,809	$ 1,721	$ 2,091	$ -	$ 14,211	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,017	$ -	$ -	$ 44,756	$ -	$ -	$ 45,773	$ 59,984		
				BSW	$ 4,238	$ 6,889	$ 6,127	$ -	$ 3,281	$ 2,924	$ 23,459	$ 13,487	$ -	$ -	$ -	$ -	$ -	$ 92	$ -	$ 1,896	$ 3,403	$ -	$ -	$ 18,878	$ 42,337		
				BSTRP	$ 1,791	$ 25,662	$ 9,023	$ 3,300	$ 337	$ -	$ 40,113	$ 7,208	$ -	$ -	$ -	$ -	$ -	$ 2,984	$ -	$ -	$ (1,597)	$ -	$ -	$ 8,595	$ 48,707		
				BSW, BSTRP	$ 3,422	$ 13,147	$ 7,093	$ 1,100	$ 2,300	$ 1,949	$ 29,010	$ 11,394	$ -	$ -	$ -	$ -	$ -	$ 1,056	$ -	$ 1,264	$ 1,736	$ -	$ -	$ 15,450	$ 44,460		
				IT/STRP	$ 1,572	$ 20,912	$ 9,383	$ 3,200	$ 125	$ -	$ 35,192	$ 2,410	$ -	$ -	$ -	$ -	$ -	$ 174	$ -	$ -	$ -	$ -	$ -	$ 2,584	$ 37,776		
				OWS	$ -	$ 6,449	$ 4,584	$ -	$ 5,023	$ -	$ 16,055	$ (122)	$ -	$ -	$ -	$ -	$ -	$ 5,540	$ -	$ -	$ 24,056	$ -	$ -	$ 29,473	$ 45,528		
				CDS	$ 6,698	$ 2,000	$ -	$ -	$ -	$ -	$ 8,698	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ (17,948)	$ -	$ -	$ (17,948)	$ (9,251)		
				DII	$ -	$ 23,769	$ 14,881	$ -	$ 534	$ -	$ 39,184	$ (139)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 816	$ -	$ -	$ 677	$ 39,861		

The Total Pilot-Unique Cost for all 39 installations was $1,960,105. Total Monitoring Costs accounted for $954,015, or 49 percent, of this total. Total Non-Monitoring Costs accounted for $1,006,090, or 51 percent, of the total. Of the Monitoring Costs categories, Associated Structures was the largest item, with a cost of $522,358. For Non-Monitoring Costs, Construction Contractor's Experience was the largest category, with a cost of $549,645. The installation with the greatest Total Pilot-Unique Cost was the MFSD constructed at the Escondido Maintenance Station (WQ ID No. 112202) with a cost of $202,704. Three of the 39 installations experienced net cost savings attributed to pilot-unique costs.

The MFSD installation had the greatest average Total Pilot-Unique Cost of all the BMP types with $202.704. The CDS installation had the lowest average total Pilot-Unique Cost, with a net savings of $9,251.

B. Actual Pilot Program Construction Cost

Section II.A presented an analysis of the total cost incurred by Caltrans for each of the 39 BMP installations in the Pilot Program, allocating costs to five distinct categories. Of the five cost categories, two categories (Pilot-Unique Monitoring Costs and Ancillary Costs) are not attributable to the construction of the BMP device. The costs allocated to these two categories include BMP monitoring required by the Pilot Program, and ancillary costs incurred for work unrelated to construction of the BMP installation.

To more accurately estimate the actual construction cost of each BMP installation in the Pilot Program, Table 5, **Actual Pilot Program Construction Cost**, excludes the costs associated with these two categories from the total. The Actual Construction Cost shown in Table 5, indicates the resulting cost of constructing the BMP devices in the Pilot Program.

For ease of reference, Table 5 presents the Total Pilot Program Construction Cost data and the costs allocated to each of the five cost categories from Table 1. In addition, Table 5 contains the following information:

Actual Construction Cost: The Actual Construction Cost is the Total Pilot Program Construction Cost less the Ancillary Cost and the Pilot-Unique Monitoring Costs. This figure represents the actual construction cost for the particular BMP device constructed as part of the Pilot Program. The cost indicated for each BMP device represents the minimum achievable construction cost using the same design, the same site selection, the same contract process, and the same time constraints as experienced in the Pilot Program.

Percent of Total Pilot Program Construction Cost: The Actual Construction Cost of each BMP installation as a percentage of the total Pilot Program construction cost for the installation.

The following Actual Pilot Program Construction Cost ranges can be observed from the percentage data for families of BMPs:

- For media filter type BMP devices, Actual Construction Cost ranges from 88 percent – 98 percent of the Total Pilot Program Cost for those types of devices.
- For basin type BMP devices, Actual Construction Cost ranges from 82 percent – 96 percent of the Total Pilot Program Cost for those types of devices.
- For biofiltration type BMP devices, Actual Construction Cost ranges from 53 percent – 91 percent of the Total Pilot Program Cost for those types of devices.
- For other BMP devices, Actual Construction Cost ranges from 68 percent – 91 percent of the Total Pilot Program Cost for those types of devices.
- For inlet protection type BMP devices, Actual Construction Cost ranges from 2 percent – 4 percent of the Total Pilot Program Cost for those types of devices.

TABLE 5 - ACTUAL PILOT PROGRAM CONSTRUCTION COST

					E	F	G	H	I	J	K	
					See Table 1, Col H	See Table 1, Col I	See Table 1, Col J	See Table 1, Col K	See Table 1 Col L	See Table 1, Col M	=F+I+J	
BMP No.	WQ ID No.	BMP Type	Site Location	Facility Type	Total Pilot Program Construction Cost	Site-Specific Cost	Ancillary Cost	Pilot-Unique Monitoring Cost	Pilot-Unique Non-Monitoring Cost	Base BMP Cost	Actual Construction Cost	Percent of Total Pilot Program Construction Cost
San Diego Area, District 11												
1	111105	EDB	I-5/Manchester (east)	Highway	$ 370,408	206,978	-	23,098	77,602	62,730	$ 347,310	94%
2	111101	EDB	I-5/SR 56	Highway	$ 161,853	77,404	-	22,015	10,082	52,353	$ 139,838	86%
3	111102	EDB	I-15/SR 78	Highway	$ 847,712	497,514	-	54,407	76,602	219,188	$ 793,305	94%
4	111103	IB	I-5/La Costa (west)	Highway	$ 272,677	194,365	-	11,371	38,254	28,686	$ 261,305	96%
5	111104	WB	I-5/La Costa (east)	Highway	$ 708,525	309,403	19,359	55,138	85,329	239,297	$ 634,029	89%
6	112201	MFSTF	Kearny Mesa Maint. Station	Maint Station	$ 325,518	57,029	-	20,162	(7,343)	255,670	$ 305,356	94%
7	112202	MFSD	Escondido Maint. Station	Maint Station	$ 453,013	63,376	-	55,477	147,227	186,933	$ 397,536	88%
8	112203	MFSA	La Costa Park & Ride	Park & Ride	$ 239,677	91,855	-	14,473	(3,606)	136,956	$ 225,204	94%
9	112204	MFSA	SR 78/I-5 Park & Ride	Park & Ride	$ 222,529	111,132	-	13,933	(22,220)	119,685	$ 208,596	94%
10	112205	BSW	SR 78/Melrose Dr	Highway	$ 142,419	45,212	3,881	9,342	47,672	36,312	$ 129,196	91%
11	112206	BSW	I-5/Palomar Airport Rd	Highway	$ 137,336	41,568	23,634	428	12,786	58,920	$ 113,274	82%
12	112207a	BSTRP	Carlsbad Maint. Station (west)	Maint Station	$ 89,243	43,451	22,299	8,682	-	14,810	$ 58,261	65%
13	112207b	IT/STRP	Carlsbad Maint. Station (east)	Maint Station	$ 142,376	58,914	22,299	23,218	347	37,599	$ 96,859	68%
Los Angeles Area, District 07												
14	073211a	BSTRP	Altadena Maint. Station	Maint Station	$ 146,400	76,399	-	40,052	3,964	25,985	$ 106,348	73%
15	073211b	IT/STRP	Altadena Maint. Station	Maint Station	$ 293,588	159,255	-	47,167	4,820	82,346	$ 246,421	84%
16	073216a	DII-SG	Foothill Maint. Station	Maint Station	$ 28,655	-	-	27,555	730	370	$ 1,100	4%
17	073216b	DII-FF	Foothill Maint. Station	Maint Station	$ 45,104	-	-	44,054	679	370	$ 1,049	2%
18	073217a	DII-SG	Las Flores Maint. Station	Maint Station	$ 47,104	-	-	46,114	620	370	$ 990	2%
19	073217b	DII-FF	Las Flores Maint. Station	Maint Station	$ 56,288	-	-	55,296	623	370	$ 993	2%
20	073218a	DII-SG	Rosemead Maint. Station	Maint Station	$ 25,177	-	-	24,077	730	370	$ 1,100	4%
21	073218b	DIIFF	Rosemead Maint. Station	Maint Station	$ 39,055	-	-	38,006	679	370	$ 1,049	3%
22	073222a	BSTRP	I-605/SR 91	Highway	$ 157,173	33,429	-	71,604	21,820	30,319	$ 85,569	54%
23	073222b	BSW	I-605/SR 91	Highway	$ 64,543	15,723	-	21,724	3,654	23,441	$ 42,819	66%
24	073223	BSW	Cerritos Maint. Station	Maint Station	$ 60,383	12,808	-	28,447	3,595	15,533	$ 31,936	53%
25	073224	BSW	I-5/I-605	Highway	$ 99,733	28,972	-	23,575	24,345	22,842	$ 76,158	76%
26	073225	BSW	I-605/Del Amo Ave	Highway	$ 127,823	25,841	-	57,237	21,216	23,529	$ 70,586	55%
27	073102	CDS	I-210/Orcas Ave	Highway	$ 39,736	21,310	-	8,052	(16,468)	26,843	$ 31,684	80%
28	073103	CDS	I-210/Fillmore Ave	Highway	$ 45,024	26,410	-	9,343	(19,428)	28,699	$ 35,681	79%
29	073101	IB	I-605/SR 91	Highway	$ 268,130	148,797	33,347	150	26,356	59,480	$ 234,633	88%
30	074101	EDB	I-5/I-605 Intersection	Highway	$ 169,732	77,917	-	11,850	46,355	33,610	$ 157,882	93%
31	074102	EDB	I-605/SR 91 Intersection	Highway	$ 111,871	64,475	-	19,632	155	27,610	$ 92,239	82%
32	074201	OWS	Alameda Maint. Station	Maint Station	$ 179,437	32,375	-	16,055	29,473	101,534	$ 163,381	91%
33	074202	MFSA	Eastern Regional Maint. Sta.	Highway	$ 353,702	84,445	-	10,916	81,872	176,469	$ 342,786	97%
34	074203	MFSA	Foothill Maint. Station	Maint Station	$ 485,947	172,806	-	7,582	79,071	226,488	$ 478,365	98%
35	074204	MFSA	Termination Park & Ride	Park & Ride	$ 471,638	93,237	-	12,249	79,287	286,865	$ 459,389	97%
36	074103	MFSA	Paxton Park & Ride	Park & Ride	$ 273,369	-	-	-	-	273,369	$ 273,369	100%
37	074206	MCTT	Via Verde Park & Ride	Park & Ride	$ 383,793	85,172	-	10,234	74,895	213,493	$ 373,559	97%
38	074104	MCTT	Metro Maint. Station	Maint Station	$ 439,333	-	-	-	-	439,333	$ 439,333	100%
39	074208	MCTT	Lakewood Park & Ride	Park & Ride	$ 464,743	83,255	-	11,299	74,319	295,869	$ 453,444	98%
			Pilot Program Total		$ 8,990,767	$ 3,040,827	$ 124,820	$ 954,015	$ 1,006,090	$ 3,865,015	$ 7,911,932	88%
			% Total Pilot Program Const. Cost		114%	38%	2%	12%	13%	49%	100%	
			Average Cost by Facility Type =	All	$ 230,532	$ 77,970	$ 3,201	$ 24,462	$ 25,797	$ 99,103	$ 202,870	
				Highway	$ 239,906	$ 111,751	$ 4,719	$ 24,111	$ 31,659	$ 67,666	$ 211,076	
				Maint Station	$ 178,539	$ 42,276	$ 2,787	$ 30,122	$ 16,576	$ 86,778	$ 145,630	
				Park & Ride	$ 342,625	$ 77,442	$ -	$ 10,365	$ 33,779	$ 221,039	$ 332,260	
			Average Cost by BMP Type =	EDB	$ 332,315	$ 184,858	$ -	$ 26,201	$ 42,159	$ 79,098	$ 306,115	
				IB	$ 270,403	$ 171,581	$ 16,674	$ 5,761	$ 32,305	$ 44,083	$ 247,969	
				WB	$ 708,525	$ 309,403	$ 19,359	$ 55,138	$ 85,329	$ 239,297	$ 634,029	
				EDB, IB, WB	$ 363,864	$ 197,107	$ 6,588	$ 24,708	$ 45,092	$ 90,369	$ 332,568	
				MFSTF	$ 325,518	$ 57,029	$ -	$ 20,162	$ (7,343)	$ 255,670	$ 305,356	
				MFSD	$ 453,013	$ 63,376	$ -	$ 55,477	$ 147,227	$ 186,933	$ 397,536	
				MFSA	$ 341,144	$ 92,246	$ -	$ 9,859	$ 35,734	$ 203,305	$ 331,285	
				MCTT	$ 429,290	$ 56,142	$ -	$ 7,178	$ 49,738	$ 316,232	$ 422,112	
				MF STF,SD,SA,TT	$ 373,933	$ 76,574	$ -	$ 14,211	$ 45,773	$ 237,375	$ 359,722	
				BSW	$ 105,373	$ 28,354	$ 4,586	$ 23,459	$ 18,878	$ 30,096	$ 77,328	
				BSTRP	$ 130,938	$ 51,093	$ 7,433	$ 40,113	$ 8,595	$ 23,705	$ 83,393	
				BSW, BSTRP	$ 113,895	$ 35,934	$ 5,535	$ 29,010	$ 15,450	$ 27,966	$ 79,350	
				IT/STRP	$ 217,982	$ 109,084	$ 11,150	$ 35,192	$ 2,584	$ 59,973	$ 171,640	
				OWS	$ 179,437	$ 32,375	$ -	$ 16,055	$ 29,473	$ 101,534	$ 163,381	
				CDS	$ 42,380	$ 23,860	$ -	$ 8,698	$ (17,948)	$ 27,771	$ 33,683	
				DII	$ 40,230	$ -	$ -	$ 39,184	$ 677	$ 370	$ 1,047	

C. Adjusted Construction Costs

Section II.B presented an analysis of the Actual Construction Cost for each of the 39 BMP installations in the Pilot Program. For that analysis, costs in two categories (Pilot-Unique Monitoring Costs and Ancillary Costs) were excluded from the Total Pilot Program Construction Cost, because they were not considered to be attributable to the construction of the BMP device. The resulting Actual Pilot Program Construction Cost was that actually incurred by Caltrans to construct the BMP for the Pilot Program.

To estimate the construction cost of the BMPs without the unique constraints and requirements of the Pilot Program, Table 6, **Adjusted Construction Cost**, excludes all Pilot-Unique Costs (Monitoring and Non-Monitoring) and Ancillary Costs. That is, if the BMP were constructed outside the Pilot Program, the cost of constructing the identical BMP device as a retrofit at the same location becomes the total of the Base BMP Cost and the Site-Specific Cost. The resulting Adjusted Construction Cost for each BMP device is used as the baseline cost for estimating the projected BMP costs presented in Section II.D.

For ease of reference, Table 6 presents the Total Pilot Program Construction Cost data and the costs allocated to each of the five cost categories from Table 1. In addition, Table 6 contains the following information:

Adjusted Construction Cost: The Adjusted Construction Cost is the Total Pilot Program Construction Cost less the Ancillary Costs (Table 3) and Total Pilot-Unique Costs (Table 4). This figure represents the estimated construction cost for the particular BMP device if constructed as a retrofit at the same facility.

Percent of Total Pilot Program Construction Cost: The Adjusted Construction Cost of each BMP installation as a percentage of the Total Pilot Program Construction Cost for the installation.

The following cost ranges can be observed from the percentage data for families of BMPs:

- For media filter type BMP devices, Adjusted Construction Cost ranges from 55 percent – 104 percent of the Total Pilot Program Construction Cost for those types of devices. (A percentage greater than 100 indicates that future costs could exceed those incurred in the Pilot Program. See the following discussion for rationale.)
- For basin type BMP devices, Adjusted Construction Cost ranges from 66 percent – 85 percent of the Total Pilot Program Construction Cost for those types of devices.
- For biofiltration type BMP devices, Adjusted Construction Cost ranges from 39 percent – 73 percent of the Total Pilot Program Construction Cost for those types of devices.
- For other BMP devices, Adjusted Construction Cost ranges from 68 percent – 122 percent of the Total Pilot Program Construction Cost for those types of devices.
- For inlet protection type BMP devices, Adjusted Construction Costs are 1 percent of the Total Pilot Program Construction Cost for those types of devices.

TABLE 6 - ADJUSTED CONSTRUCTION COST

					E	F	G	H	I	J	K	
					See Table 1, Col H	See Table 1, Col I	See Table 1, Col J	See Table 1, Col K	See Table 1 Col L	See Table 1, Col M	=F+J	
BMP No.	WQ ID No.	BMP Type	Site Location	Facility Type	Total Pilot Program Construction Cost	Site-Specific Cost	Ancillary Cost	Pilot-Unique Monitoring Cost	Pilot-Unique Non-Monitoring Cost	Base BMP Cost	Adjusted Construction Cost	Percent of Total Pilot Program Construction Cost
San Diego Area, District 11												
1	111105	EDB	I-5/Manchester (east)	Highway	$ 370,408	206,978	-	23,098	77,602	62,730	$ 269,708	73%
2	111101	EDB	I-5/SR 56	Highway	$ 161,853	77,404	-	22,015	10,082	52,353	$ 129,757	80%
3	111102	EDB	I-15/SR 78	Highway	$ 847,712	497,514	-	54,407	76,602	219,188	$ 716,703	85%
4	111103	IB	I-5/La Costa (west)	Highway	$ 272,677	194,365	-	11,371	38,254	28,686	$ 223,052	82%
5	111104	WB	I-5/La Costa (east)	Highway	$ 708,525	309,403	19,359	55,138	85,329	239,297	$ 548,700	77%
6	112201	MFSTF	Kearny Mesa Maint. Station	Maint Station	$ 325,518	57,029	-	20,162	(7,343)	255,670	$ 312,699	96%
7	112202	MFSD	Escondido Maint. Station	Maint Station	$ 453,013	63,376	-	55,477	147,227	186,933	$ 250,309	55%
8	112203	MFSA	La Costa Park & Ride	Park & Ride	$ 239,677	91,855	-	14,473	(3,606)	136,956	$ 228,811	95%
9	112204	MFSA	SR 78/I-5 Park & Ride	Park & Ride	$ 222,529	111,132	-	13,933	(22,220)	119,685	$ 230,817	104%
10	112205	BSW	SR 78/Melrose Dr	Highway	$ 142,419	45,212	3,881	9,342	47,672	36,312	$ 81,524	57%
11	112206	BSW	I-5/Palomar Airport Rd	Highway	$ 137,336	41,568	23,634	428	12,786	58,920	$ 100,489	73%
12	112207a	BSTRP	Carlsbad Maint. Station (west)	Maint Station	$ 89,243	43,451	22,299	8,682	-	14,810	$ 58,261	65%
13	112207b	IT/STRP	Carlsbad Maint. Station (east)	Maint Station	$ 142,376	58,914	22,299	23,218	347	37,599	$ 96,512	68%
Los Angeles Area, District 07												
14	073211a	BSTRP	Altadena Maint. Station	Maint Station	$ 146,400	76,399	-	40,052	3,964	25,985	$ 102,384	70%
15	073211b	IT/STRP	Altadena Maint. Station	Maint Station	$ 293,588	159,255	-	47,167	4,820	82,346	$ 241,601	82%
16	073216a	DII-SG	Foothill Maint. Station	Maint Station	$ 28,655	-	-	27,555	730	370	$ 370	1%
17	073216b	DII-FF	Foothill Maint. Station	Maint Station	$ 45,104	-	-	44,054	679	370	$ 370	1%
18	073217a	DII-SG	Las Flores Maint. Station	Maint Station	$ 47,104	-	-	46,114	620	370	$ 370	1%
19	073217b	DII-FF	Las Flores Maint. Station	Maint Station	$ 56,288	-	-	55,296	623	370	$ 370	1%
20	073218a	DII-SG	Rosemead Maint. Station	Maint Station	$ 25,177	-	-	24,077	730	370	$ 370	1%
21	073218b	DIIFF	Rosemead Maint. Station	Maint Station	$ 39,055	-	-	38,006	679	370	$ 370	1%
22	073222a	BSTRP	I-605/SR 91	Highway	$ 157,173	33,429	-	71,604	21,820	30,319	$ 63,749	41%
23	073222b	BSW	I-605/SR 91	Highway	$ 64,543	15,723	-	21,724	3,654	23,441	$ 39,165	61%
24	073223	BSW	Cerritos Maint. Station	Maint Station	$ 60,383	12,808	-	28,447	3,595	15,533	$ 28,341	47%
25	073224	BSW	I-5/I-605	Highway	$ 99,733	28,972	-	23,575	24,345	22,842	$ 51,814	52%
26	073225	BSW	I-605/Del Amo Ave	Highway	$ 127,823	25,841	-	57,237	21,216	23,529	$ 49,370	39%
27	073102	CDS	I-210/Orcas Ave	Highway	$ 39,736	21,310	-	8,052	(16,468)	26,843	$ 48,153	121%
28	073103	CDS	I-210/Fillmore Ave	Highway	$ 45,024	26,410	-	9,343	(19,428)	28,699	$ 55,109	122%
29	073101	IB	I-605/SR 91	Highway	$ 268,130	148,797	33,347	150	26,356	59,480	$ 208,276	78%
30	074101	EDB	I-5/I-605 Intersection	Highway	$ 169,732	77,917	-	11,850	46,355	33,610	$ 111,527	66%
31	074102	EDB	I-605/SR 91 Intersection	Highway	$ 111,871	64,475	-	19,632	155	27,610	$ 92,084	82%
32	074201	OWS	Alameda Maint. Station	Maint Station	$ 179,437	32,375	-	16,055	29,473	101,534	$ 133,908	75%
33	074202	MFSA	Eastern Regional Maint. Sta.	Highway	$ 353,702	84,445	-	10,916	81,872	176,469	$ 260,914	74%
34	074203	MFSA	Foothill Maint. Station	Maint Station	$ 485,947	172,806	-	7,582	79,071	226,488	$ 399,294	82%
35	074204	MFSA	Termination Park & Ride	Park & Ride	$ 471,638	93,237	-	12,249	79,287	286,865	$ 380,102	81%
36	074103	MFSA	Paxton Park & Ride	Park & Ride	$ 273,369	-	-	-	-	273,369	$ 273,369	100%
37	074206	MCTT	Via Verde Park & Ride	Park & Ride	$ 383,793	85,172	-	10,234	74,895	213,493	$ 298,665	78%
38	074104	MCTT	Metro Maint. Station	Maint Station	$ 439,333	-	-	-	-	439,333	$ 439,333	100%
39	074208	MCTT	Lakewood Park & Ride	Park & Ride	$ 464,743	83,255	-	11,299	74,319	295,869	$ 379,125	82%
			Pilot Program Total		$ 8,990,767	$ 3,040,827	$ 124,820	$ 954,015	$ 1,006,090	$ 3,865,015	$ 6,905,842	77%
	% Total Pilot Program Const. Cost				130%	44%	2%	14%	15%	56%	100%	
		Average Cost by Facility Type =		All	$ 230,532	$ 77,970	$ 3,201	$ 24,462	$ 25,797	$ 99,103	$ 177,073	
				Highway	$ 239,906	$ 111,751	$ 4,719	$ 24,111	$ 31,659	$ 67,666	$ 179,417	
				Maint Station	$ 178,539	$ 42,276	$ 2,787	$ 30,122	$ 16,576	$ 86,778	$ 129,054	
				Park & Ride	$ 342,625	$ 77,442	$ -	$ 10,365	$ 33,779	$ 221,039	$ 298,481	
		Average Cost by BMP Type =		EDB	$ 332,315	$ 184,858	$ -	$ 26,201	$ 42,159	$ 79,098	$ 263,956	
				IB	$ 270,403	$ 171,581	$ 16,674	$ 5,761	$ 32,305	$ 44,083	$ 215,664	
				WB	$ 708,525	$ 309,403	$ 19,359	$ 55,138	$ 85,329	$ 239,297	$ 548,700	
				EDB, IB, WB	$ 363,864	$ 197,107	$ 6,588	$ 24,708	$ 45,092	$ 90,369	$ 287,476	
				MFSTF	$ 325,518	$ 57,029	$ -	$ 20,162	$ (7,343)	$ 255,670	$ 312,699	
				MFSD	$ 453,013	$ 63,376	$ -	$ 55,477	$ 147,227	$ 186,933	$ 250,309	
				MFSA	$ 341,144	$ 92,246	$ -	$ 9,859	$ 35,734	$ 203,305	$ 295,551	
				MCTT	$ 429,290	$ 56,142	$ -	$ 7,178	$ 49,738	$ 316,232	$ 372,374	
				MF STF,SD,SA,TT	$ 373,933	$ 76,574	$ -	$ 14,211	$ 45,773	$ 237,375	$ 313,949	
				BSW	$ 105,373	$ 28,354	$ 4,586	$ 23,459	$ 18,878	$ 30,096	$ 58,450	
				BSTRP	$ 130,938	$ 51,093	$ 7,433	$ 40,113	$ 8,595	$ 23,705	$ 74,798	
				BSW, BSTRP	$ 113,895	$ 35,934	$ 5,535	$ 29,010	$ 15,450	$ 27,966	$ 63,899	
				IT/STRP	$ 217,982	$ 109,084	$ 11,150	$ 35,192	$ 2,584	$ 59,973	$ 169,057	
				OWS	$ 179,437	$ 32,375	$ -	$ 16,055	$ 29,473	$ 101,534	$ 133,908	
				CDS	$ 42,380	$ 23,860	$ -	$ 8,698	$ (17,948)	$ 27,771	$ 51,631	
				DII	$ 40,230	$ -	$ -	$ 39,184	$ 677	$ 370	$ 370	

Adjustments for Pilot-Unique Non-Monitoring costs do not imply recommendations for reducing or eliminating construction costs, but are adjustments associated with the unique requirements of the Pilot Program that would not be expected to impact the construction of the same BMP device as a retrofit outside the Pilot Program.

The following discussion provides a rationale for excluding Pilot-Unique Non-Monitoring Costs to derive the Adjusted Construction Costs shown in Table 6. For each of the Pilot Unique Non-Monitoring Costs (detailed in Table 4), this section discusses the actual impact to the Pilot Program and the rationale for excluding it from the Adjusted Construction Cost.

Accelerated Time of Completion: For the Pilot Program, accelerated schedules added costs for the installation of sod instead of grass seed, labor overtime, and reconstruction of concrete structures. Cost savings were realized from savings on performance bonds as a result of the accelerated work schedule. Under circumstances in which external time constraints are not applied, such costs adjustments would not be expected.

Site Selection Artificialities: For the Pilot Program, extensive shoring to construct some MFSAs and MCTTs was needed, but none of the cost was allocated to Site Selection Artificialities. Shoring costs are directly attributable to available space during construction. For retrofits of existing facilities, design and construction are dependent on available space to ensure the proper functioning of the facility. Therefore, no costs attributable to site selection artificialities would be expected.

Sharing of Costs: For the Pilot Program, no costs were allocated to Sharing of Costs as a result of the unique requirements of the Pilot Program. Since BMP device construction would be done as a retrofit, it is not anticipated that cost sharing would be a factor for reducing costs. Additional analysis related to costs due to construction process (retrofit, new construction, or redevelopment) is presented in Section IV, Comparison of Projected Construction Costs to Other Agency Construction Costs.

Scoping/Site Limitations: For the Pilot Program, no costs were allocated to Scoping/Site Limitations as a result of the unique requirements of the Pilot Program. Caltrans does not typically construct projects outside its own right-of-way; therefore, with or without the Pilot Program, the devices would have been constructed on the Caltrans right-of-way. Additional analysis related to costs due to regional partnerships is addressed in Section IV, Comparison of Projected Construction Costs to Other Agency Construction Costs.

Lack of Competitive Bid: For the Pilot Program, no costs were allocated to Lack of Competitive Bid due to the unique requirements of the Pilot Program. An increase in the number of bidders may occur as contractors become more experienced with building the BMP devices. If general economic conditions continue, it is not expected that interest will increase from current levels; therefore, there is no basis to project cost adjustments in anticipation of a more competitive bidding environment.

Standard Designs For the Pilot Program, no costs were allocated to Standard Designs because any non-standard designs constructed as part of the program would have been needed at the same location, with or without the constraints of the Pilot Program. Additional analysis regarding cost adjustments due to standard designs of facilities and components is addressed in Section IV, Comparison of Projected Construction Costs to Other Agency Construction Costs.

Site-Specific Designs: Seventeen sites incurred additional construction costs attributable to the lack of identifying site-specific design requirements in the Pilot Program. These additional costs can be reduced or eliminated using design personnel with greater experience with BMP design and/or construction schedules that allow greater geo-technical investigation. Under circumstances where artificial time constraints are not applied, such costs would not be anticipated.

Overdesigned Features: For the Pilot Program, four installations incurred additional costs due to overdesigned features. Experience gained through the Pilot Program and ongoing activities may eliminate costs associated with this item in the future.

Vector Control: . Eight sites incurred additional construction costs attributable to vector control issues in the Pilot Program. With a greater familiarity with vector control issues, these costs may be eliminated.

Construction Contractor's Experience: Twenty-three sites incurred additional construction costs attributable to contractor inexperience in the Pilot Program. With increased contractor familiarity with the construction of BMP devices, these costs may be eliminated.

Quantity of BMPs: For the Pilot Program, no costs were allocated to Quantity of BMPs as a result of the unique requirements of the Pilot Program. Since BMP construction would be done as a retrofit (low BMP quantities at numerous sites) with or without the Pilot Program, it is not anticipated that the quantity of BMPs would be a factor for reducing costs. Additional analysis related to costs due to low quantities of BMP retrofit installations is addressed in Section IV, Comparison of Projected Construction Costs to Other Agency Construction Costs.

Size of BMPs: For the Pilot Program, no cost adjustments were allocated to Size of BMPs resulting from the unique requirements of the Pilot Program. For each BMP installation in the Pilot Program, the site-specific design reflected the optimum size needed treat the storm water discharge/volume anticipated at that site. That is, Pilot Program requirements did not affect the sizes of the constructed BMPs.

It is anticipated that at locations other than those in the Pilot Program, larger or smaller BMP devices may be required, with resulting impacts to cost per water quality design unit. Additional analyses related to the costs associated with BMP device size, is addressed in Section IV, Comparison of Projected Construction Costs to Other Agency Construction Costs.

D. Projected Construction Costs

Section II.C identifies the Adjusted Construction Cost for each of the 39 BMP installations in the Pilot Program. The Adjusted Construction Cost represents the estimated cost to construct the identical BMP device as a retrofit at the identical location, excluding any cost adjustments associated with the requirements of the Pilot Program or Ancillary Costs.

In this section, the Adjusted Construction Cost data is used as a baseline to estimate a Projected Construction Cost for each of the 13 BMP types (EDB, BS, DII, etc.) for various water quality design units.

Projected Construction Costs are estimates based on the projected Base BMP Cost, projected Required Site-Specific Costs, and projected Retrofit Site-Specific Costs for an applicable water quality design for the BMP type.

The following steps were followed to derive the Projected Construction Costs for the 13 BMP types:

1. For each of the 39 BMP installations in the Pilot Program, Base BMP Cost, Required Site-Specific Cost, and the Retrofit Site-Specific Cost were identified.
2. For each of the 39 BMP installations, a cost based on the water quality design unit was calculated. The water quality design unit for a specific BMP type is either by volume (acre-ft) or by discharge rate (cubic feet per second or cfs), as shown in the following table.

BMP Type		No. of Installations	Water Quality Design Unit
Extended Detention Basin	EDB	5	Volume - acre-ft
Media Filter (Austin Sand Filter)	MFSA	6 (5*)	Discharge – cfs
Media Filter (Delaware Sand Filter)	MFSD	1	Discharge - cfs
Multi-Chambered Treatment Train	MCTT	3 (2*)	Discharge - cfs
Media Filter (Storm Filter)	MFSTF	1	Discharge - cfs
Biofiltration Swale	BSW	6	Discharge - cfs
Biofiltration Strip	BSTRP	3	Discharge - cfs
Infiltration Basin	IB	2	Volume - acre-ft
Infiltration Trench/Strip	IT/STRP	2	Discharge - cfs
Wet Basin	WB	1	Volume - acre-ft
Drain Inlet Insert	DII	6	Discharge - cfs
Oil/Water Separator	OWS	1	Discharge - cfs
Continuous Deflection Separator	CDS	2	Discharge - cfs

*No. of installations for which data was analyzed for the report.

3. The unit cost of each BMP installation by BMP type was plotted. For example, one graph plots the unit costs of the five EDB installations in the Pilot Program.

4. Unit cost curves for each BMP type were developed using a simple power trend-line with the form $y=cx^6$ drawn through the points for the Base BMP Unit Cost, the Required Site-Specific Unit Costs, and Retrofit Site-Specific Unit Cost.
5. Using the unit cost curves for a range of water quality design units, Projected Unit Costs and Projected Construction Costs were graphed.

Sections II.D.1 through II.D.13 contain the projected construction cost analyses for the 13 BMP types in the Pilot Program, presented in the order shown in the preceding table.

Each section contains the following tables and graphs to present unit cost and projected cost data for the BMP type:

- Adjusted Unit Cost table (results of steps 1 and 2 above)
- Adjusted Unit Cost bar graph (results of step 3 above)
- Adjusted Unit Cost Curves graph (results from step 4 above)
- Projected Construction Cost table (tabular results of step 5 above)
- Projected Unit Costs bar graph (graphical results of step 5 above)
- Projected Construction Cost bar graph (graphical results of step 5 above)

The formats of the tables and graphs are identical for each of the BMP types, with the exception of the water quality design unit identified for the BMP device, which is either acre-ft or cfs, as appropriate.

The formats of the tables and graphs are described below.

Adjusted Unit Costs Table

The table of Adjusted Unit Costs shows the derivation of the water quality design unit cost for each of the installations of that type of BMP in the Pilot Program. The table contains the following information listed in ascending order by water quality design size.

WQ ID No.: Unique Water Quality (WQ) Site Identification (ID) Number assigned to the 39 BMP installation in the Pilot Program. Refer to Section II.A for details.

BMP Type: BMP type using the abbreviations shown in the table on the previous page.

Site Location: The physical location of the BMP device by road, highway, or maintenance station name. See Section II.A for details.

Base BMP Cost: From Table 6 in Section II.C.

Required Site-Specific Cost: The estimated construction cost (over the Base BMP Cost) for site-specific requirements to construct that BMP installation. These are construction costs expected for the particular BMP installation, regardless of the construction process (retrofit, as part of redevelopment, new construction, etc.), and would expect to be incurred at a similar level on all construction sites for the same BMP type. Site-specific work associated with these costs includes: drainage systems, access roads, site clearing and grubbing, resolution of utility conflicts, environmental mitigation, dewatering, removal of buried objects, and safety and security measures.

Retrofit Site-Specific Cost: The estimated construction cost (over the Base BMP Cost) for site-specific requirements to construct that BMP installation as a retrofit. These costs may not apply to construction of the BMP installation as a part of new construction or redevelopment. Costs associated with retrofit include: traffic control, limited space, limited head, facility restoration, and miscellaneous impacts.

Total Adjusted Construction Cost: From Table 6 in Section II.C. The cost to construct the identical BMP device at the identical location as identified in the Pilot Program, but without the constraints and additional requirements imposed by the Pilot Program, or costs associated with Ancillary items.

Tributary Drainage Area: The area of the earth's surface upon which falling precipitation flows to the BMP device at the installation location.

Water Quality Design Discharge: The water quality discharge rate (expressed in cfs) for which the BMP device was designed.

Water Quality Design Volume: The water quality volume (expressed in acre-ft) for which the BMP device was designed.

Base BMP Unit Cost: The base construction cost of the BMP device per water quality design unit (Base BMP Cost divided by Water Quality Design Discharge/Volume).

Required Site Specific Unit Cost: The construction cost associated with site-specific requirements per water quality design unit (Required Site-Specific Cost divided by Water Quality Design Discharge/Volume).

Retrofit Site-Specific Unit Cost The construction cost associated with retrofit-specific requirements per water quality design unit (Retrofit Site- Specific Cost divided by Water Quality Design Discharge/Volume).

Total Adjusted Unit Cost: Total construction cost of the BMP device per water quality design unit (Base BMP Unit Cost + Required Site-Specific Unit Cost + Retrofit Site-Specific Unit Cost).

Adjusted Unit Cost Bar Graph

The Adjusted Unit Cost bar graph provides a graphical representation of the unit cost data from the Adjusted Unit Cost table by BMP installation. The x-axis identifies the WQ ID No. for the BMP installation. The y-axis shows the unit cost in dollars per water quality design unit.

Each bar in the graph represents the Total Adjusted Unit Cost for the indicated installation of that type of BMP in the Pilot Program. The three segments of the bar indicate the unit cost attributed to the Base BMP Unit Cost, Required Site-Specific Unit Cost and the Retrofit Site-Specific Unit Cost.

Adjusted Unit Cost Curves Graph

The Adjusted Unit Cost Curves graph provides a graphical analysis of the unit cost data from the Adjusted Unit Costs table by unit cost category (Base BMP Unit Cost, Required Site-Specific Unit Cost and Retrofit Site-Specific Unit Cost). The x-axis shows the range of water quality design units. The y-axis shows the unit cost in dollars per water quality design unit.

Based on the plotted unit costs, the cost curve illustrates the trends in unit cost for the three cost categories over a range of water quality design units. The resulting curve equations are shown to the right of the chart.

Projected Construction Costs Table

The Projected Construction Costs table shows the derivation of the projected construction unit costs and Total Projected Construction Cost for the BMP type for various water quality design units. The table contains the following information:

WQ ID No.: As defined in Section II.A.

Site Location: Typical site where the BMP type is constructed.

Projected Base BMP Cost: For the indicated water quality design unit, the projected cost for constructing that type of BMP, excluding costs associated with site-specific requirements or retrofit-specific requirements. This value is calculated using the appropriate curve equation from the Adjusted Unit Cost Curve graph for each of the water quality design unit values.

Projected Required Site-Specific Cost: For the indicated water quality design unit, the projected cost (above the Base BMP Cost) attributable to site-specific requirements to construct that type of BMP. This value is calculated using the appropriate curve equation from the Adjusted Unit Cost Curve graph for each of the water quality design unit values.

Projected Retrofit Site-Specific Cost: For the indicated water quality design unit, the projected cost (above the Base BMP Cost) attributable to constructing that type of BMP as a retrofit. This value is calculated using the appropriate curve equation from the Adjusted Unit Cost Curve graph for each of the water quality design unit values.

Projected Total Construction Cost:	For the indicated water quality design unit, the total projected construction cost to construct that type of BMP (Projected Base BMP Cost + Projected Requirement Site-Specific Cost + Projected Retrofit Site-Specific Cost).
Tributary Drainage Area:	The area of the earth's surface upon which falling precipitation flows to the BMP device at the installation location.
Water Quality Design Discharge:	The water quality design discharges for which projected costs were developed. The selected water quality design discharges are representative of the BMP sizes in the Pilot Program and other volumes to show trends and project costs over a range of typical values.
Water Quality Design Volume:	The water quality design volumes for which projected costs were developed. The selected water quality design volumes are representative of the BMP sizes in the Pilot Program and other volumes to show trends and project costs over a range of typical values.
Projected Base BMP Unit Cost:	For the indicated water quality design unit, the projected base construction cost of the BMP device per water quality design unit (Projected Base BMP Cost divided by Water Quality Design Discharge/Volume).
Projected Required Site-Specific Unit Cost:	For the indicated water quality design unit, the projected construction cost associated with site-specific requirements per water quality design unit (Projected Required Site- Specific Cost divided by Water Quality Design Discharge/Volume).
Projected Retrofit Site-Specific Unit Cost:	For the indicated water quality design unit, the projected construction cost associated with retrofit-specific requirements per water quality design unit (Projected Retrofit Site-Specific Cost divided by Water Quality Design Discharge/Volume).
Total Projected Unit Cost:	For the indicated water quality design unit, the total projected construction cost of the BMP device per water quality design unit (Projected Base BMP Unit Cost + Projected Required Site-Specific Unit Cost + Projected Retrofit Site-Specific Unit Cost).

Projected Unit Cost Bar Graph

The Projected Unit Cost bar graph provides a graphical representation of the projected unit cost data from the Projected Construction Costs table in ascending order by water quality design unit. The x-axis shows the water quality design units (discharges/volumes). The y-axis shows the unit cost in dollars per water quality design unit.

Each bar in the graph represents the Total Projected Unit Cost to construct that type of BMP at that water quality design discharge/volume. The three segments of the bar indicate the portion of the unit cost attributed to the Projected Base BMP Unit Cost, Projected Required Site-Specific Unit Cost and the Projected Retrofit Site-Specific Unit Cost.

Projected Construction Cost Bar Graph

The Projected Construction Cost bar graph provides a graphical representation of the projected total construction cost data from the Projected Construction Cost table. The x-axis shows the water quality design units (acre ft. or cfs) in ascending order. The y-axis shows the total projected cost to construct that type of BMP for that water quality design unit.

Each bar in the graph represents the Projected Total Construction Cost to construct that type of BMP for that water quality design unit. The three segments of the bar indicate the portion of the projected total cost attributed to the Projected Base BMP Cost, Projected Required Site-Specific Cost and the Projected Retrofit Site-Specific Cost.

1. Extended Detention Basin – Projected Construction Cost Analysis

This section projects construction costs for the extended detention basin (EDB) BMP type. Table 1-A presents the adjusted unit costs for the five EDBs constructed as part of the Caltrans Pilot Program, listed in ascending order by water quality design size. Water quality design units for the EDB are specified by volume in acre-ft.

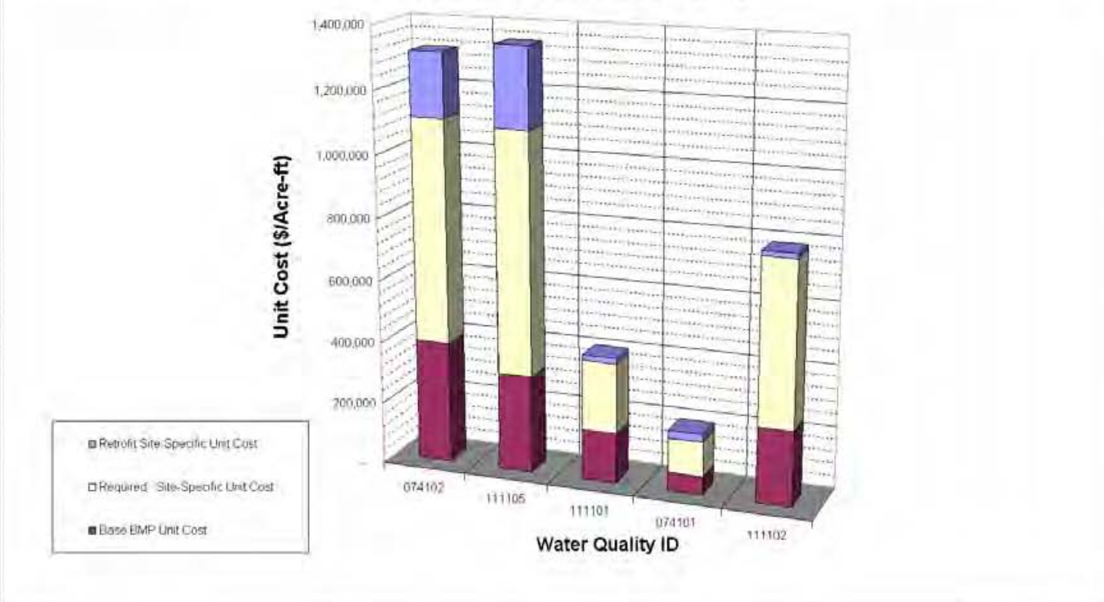
For the five EDB installations in the Pilot Program, the Adjusted Unit Costs ranged from $195,662 to $1,348,541 per acre-foot, as shown in Graph 1-1.

For all five installations, the Required Site-Specific Unit Cost was the largest component of the total adjusted unit cost, followed by Base BMP Unit Cost, as shown by the cost curves in Graph 1-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design volume increases.

TABLE 1-A. ADJUSTED UNIT COSTS - EDBs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Extended Detention Basins													
074102	EDB	I-605/SR 91 Intersection	27,610	50,175	14,300	92,084	0.80	1.10	0.07	394,422	716,783	204,286	1,315,491
111105	EDB	I-5/Manchester (east)	62,730	155,819	51,158	269,708	4.80	4.63	0.20	313,652	779,097	255,792	1,348,541
111101	EDB	I-5/SR 56	52,353	71,925	5,479	129,757	5.30	5.72	0.32	163,604	224,766	17,120	405,490
074101	EDB	I-5/I-605 Intersection	33,610	63,617	14,300	111,527	6.40	5.20	0.57	58,965	111,608	25,088	195,662
111102	EDB	I-15/SR 78	219,188	482,780	14,734	716,703	13.50	9.50	0.91	240,866	530,528	16,191	787,585

GRAPH 1-1. Adjusted Unit Cost - EDBs



GRAPH 1-2. Adjusted Unit Cost Curves - EDBs

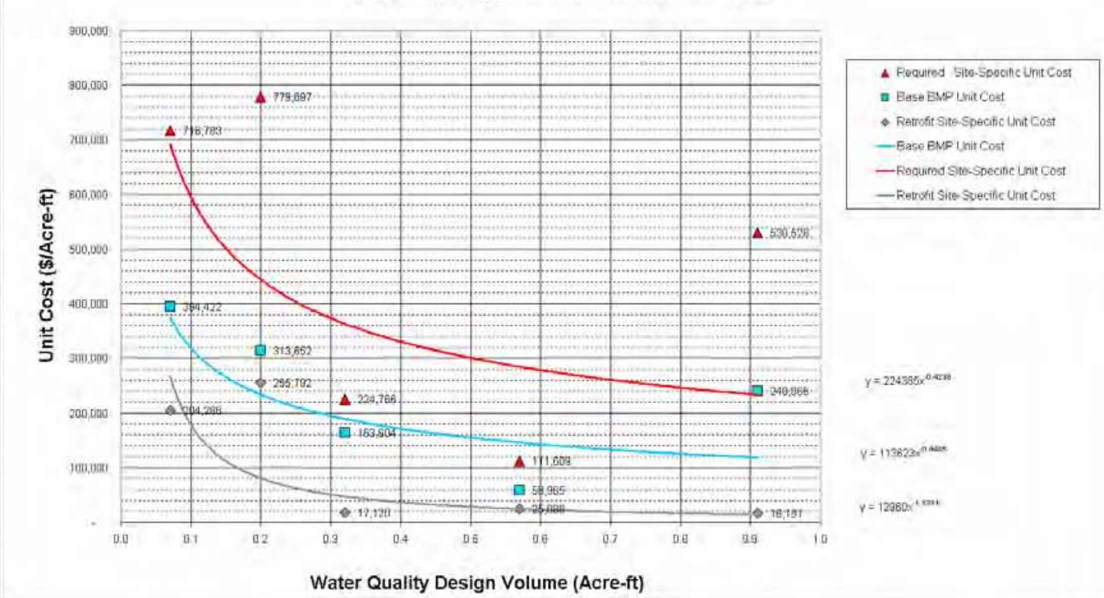


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Table 1-B shows projected cost data derived using the cost curve equations from Graph 1-2 for 14 different water quality design volumes; the five associated with the Pilot Program installations, and nine additional volumes representing a typical range of values. The data are listed in ascending order by water quality design volume.

For the 14 water quality design volumes in the table, the Total Projected Unit Costs ranged from \$256,422 to \$1,334,324, as shown in Graph 1-3. The graph shows that unit cost decreases as design volume increases. For all 14 water quality design volumes, the Projected Required Site-Specific Unit Cost was the largest component of the total projected unit cost, followed by the Projected Base BMP Unit Cost.

Graph 1-4 graphically represents the Total Projected Construction Cost data from Table 1-B in ascending order by water quality design volume. This graph shows the increase in the total projected cost of constructing an EDB as the water quality design volume increases. The graph also shows that costs for Projected Required Site-Specific Cost accounts for the greatest portion of the total cost regardless of design volume.

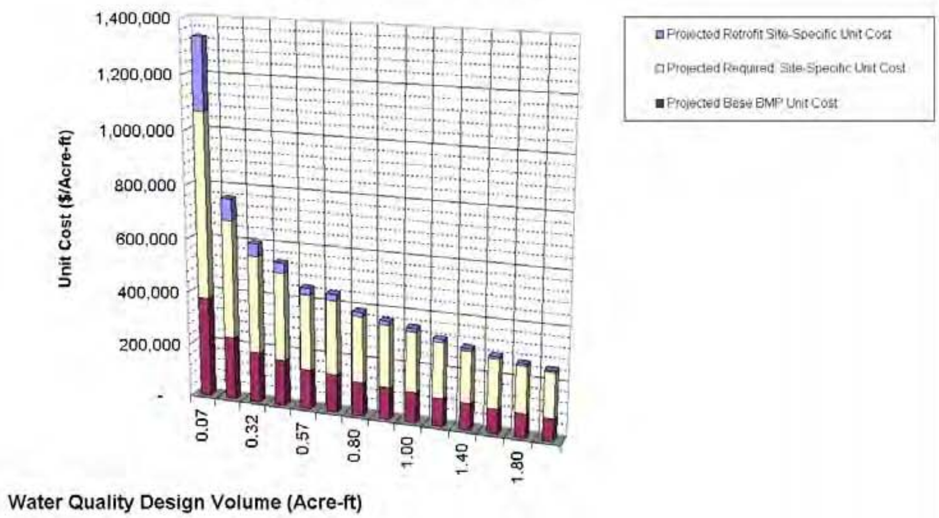
A maximum design volume of 2.0 acre-ft was used for the analysis because the EDBs constructed in the Pilot Program were relatively small (compared to those constructed by other agencies). One could reasonably expect the same unit cost savings trend to continue for greater water quality design volumes based on the retrofit construction process.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for EDBs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an EDB unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the EDB is constructed using a process other than retrofit of an existing facility.

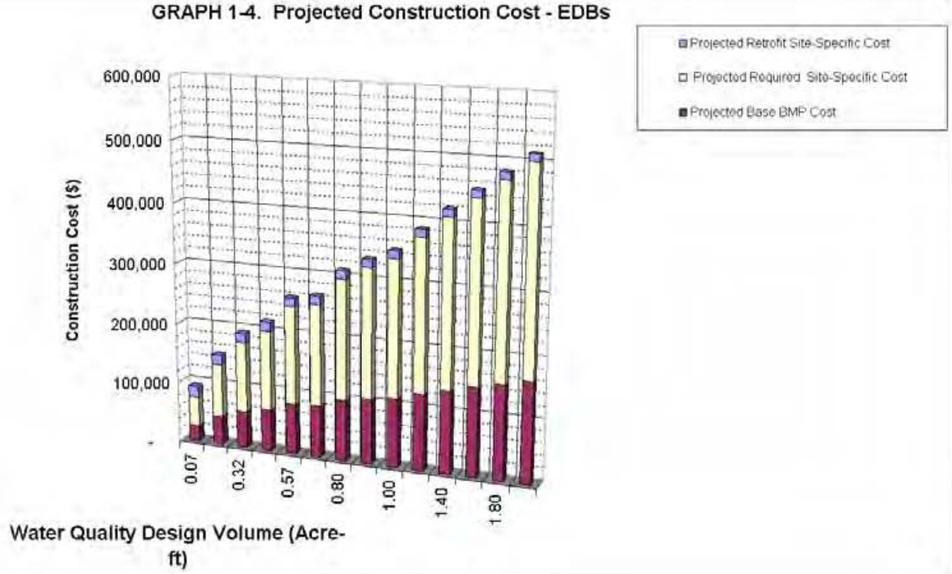
TABLE 1-B. PROJECTED CONSTRUCTION COSTS - EDBs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Extended Detention Basins												
74102	Typical Sites with Indicated Water Quality Volume	26,214	48,477	18,711	93,403			0.07	374,490	692,534	267,300	1,334,324
111105		46,772	88,766	16,186	151,724			0.20	233,859	443,831	80,929	758,619
111101		60,612	116,375	15,169	192,156			0.32	189,412	363,673	47,402	600,486
		68,549	132,343	14,708	215,600			0.40	171,373	330,857	36,771	539,001
74101		83,336	162,304	14,006	259,646			0.57	146,203	284,744	24,572	455,519
		85,727	167,172	13,907	266,806			0.60	142,878	278,621	23,179	444,677
		100,466	197,312	13,366	311,144			0.80	125,583	246,640	16,707	388,930
111102		107,864	212,517	13,130	333,511			0.91	118,532	233,535	14,428	366,496
		113,623	224,385	12,960	350,968			1.00	113,623	224,385	12,960	350,968
		125,642	249,240	12,638	387,520			1.20	104,702	207,700	10,531	322,933
		136,790	272,391	12,372	421,553			1.40	97,707	194,565	8,837	301,109
		147,244	294,176	12,146	453,566			1.60	92,028	183,860	7,591	283,479
		157,126	314,834	11,950	483,910			1.80	87,292	174,908	6,639	268,839
		166,527	334,539	11,777	512,843			2.00	83,263	167,270	5,888	256,422

GRAPH 1-3. Projected Unit Cost - EDBs



GRAPH 1-4. Projected Construction Cost - EDBs



2. Media Filter (Austin Sand Filter) – Projected Construction Cost Analysis

This section projects construction costs for the Media Filter - Austin Sand Filter (MFSA) BMP type. Table 2-A presents the adjusted unit costs for five MFSA devices constructed as part of the Caltrans Pilot Program, listed in ascending order by water quality design size. Water quality design units for the MFSA are specified by discharge in cfs. There were six MFSA installations as part of the Pilot Program, but only five installations were included in this analysis due to lack of available data for one installation.

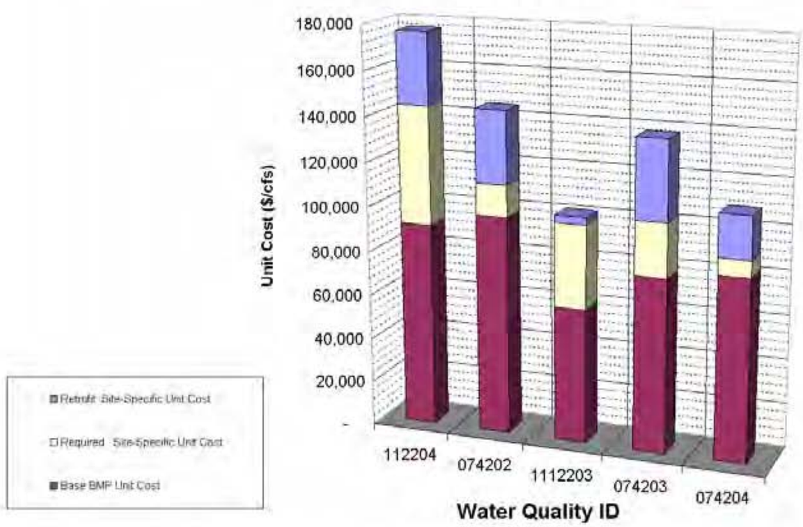
For the five MFSA installations analyzed from the Pilot Program, the Total Adjusted Unit Costs ranged from \$101,244 to \$176,600 per cfs, as shown in Graph 2-1.

For all five installations, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. For three installations, the Retrofit Site-Specific Unit Cost was the second most costly category, with the Required Site-Specific Cost the second most costly category for the remaining two installations. The cost curves for each category, are shown in Graph 2-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 2-A. ADJUSTED UNIT COST - MFSAs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Media Filter (Austin Sand Filter)													
112204	MFSA	SR 78/I-5 Park & Ride	119,685	69,087	42,045	230,817	0.80	1.31	0.09	91,572	52,659	32,169	176,600
074202	MFSA	Eastern Regional Maint. Sta.	176,469	26,032	58,413	260,914	1.50	1.80	0.09	98,038	14,462	32,452	144,952
1112203	MFSA	La Costa Park & Ride	136,956	84,789	7,066	228,811	2.70	2.26	0.19	60,600	37,517	3,126	101,244
074203	MFSA	Foothill Maint. Station	226,488	70,218	102,589	399,294	1.80	2.90	0.18	78,099	24,213	35,375	137,688
074204	MFSA	Termination Park & Ride	286,865	26,031	67,206	380,102	2.80	3.50	0.18	81,961	7,437	19,202	108,601

GRAPH 2-1. Adjusted Unit Cost - MFSAs



GRAPH 2-2. Adjusted Unit Cost Curves - MFSAs

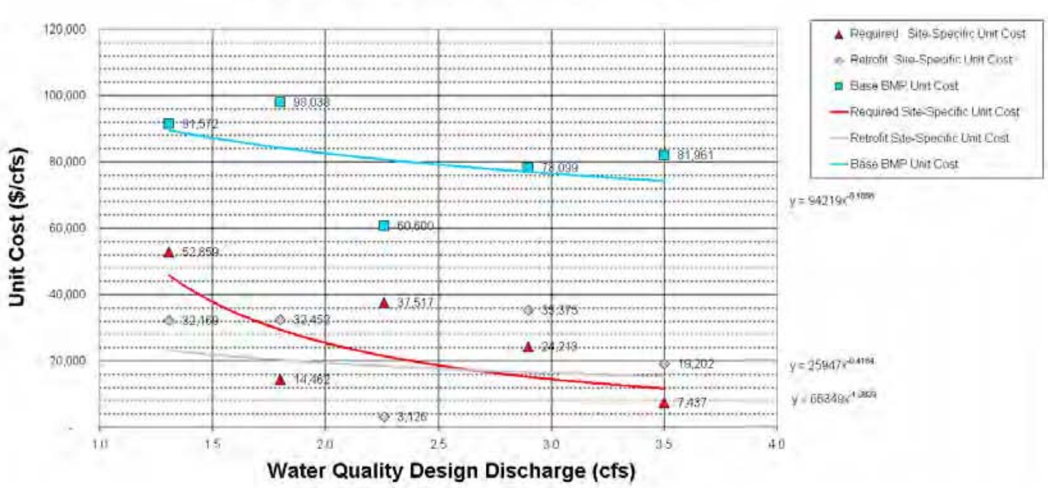


Table 2-B shows projected cost data derived using the cost curve equations from Graph 2-2 for 10 different water quality design discharges; the five associated with the Pilot Program installations, and five additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

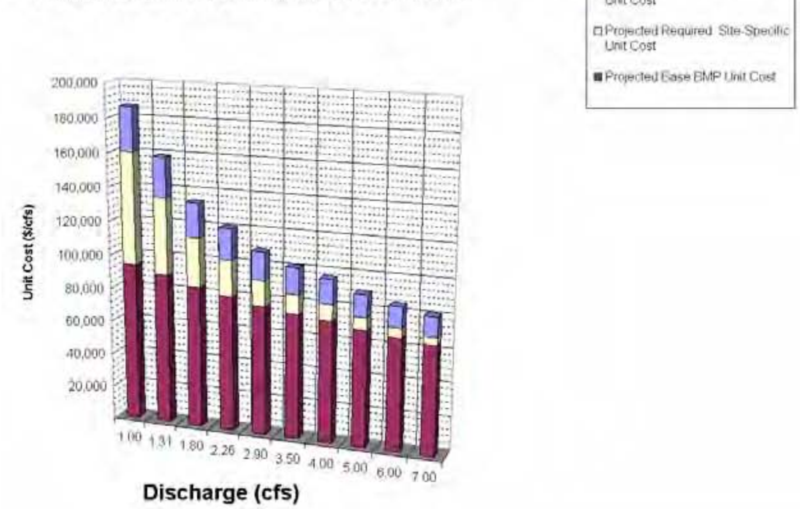
For the 10 water quality design discharges in the table, the Total Projected Unit Costs ranged from $81,114 to $186,515, as shown in Graph 2-3. The graph shows that total unit cost decreases as design discharge increases. For all 10 water quality design discharges, the Projected Base BMP Unit Cost was the largest component of the total projected unit cost. For the four projections with the smallest design discharge, the Projected Required Site-Specific Unit Costs were the second most costly category. For the six largest design discharges, the Projected Retrofit Site-Specific Unit Costs were the second most costly category.

Graph 2-4 graphically represents the Total Projected Construction Cost data from Table 2-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing an MFSA as the water quality design discharge increases. The graph also shows that costs for Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design discharge.

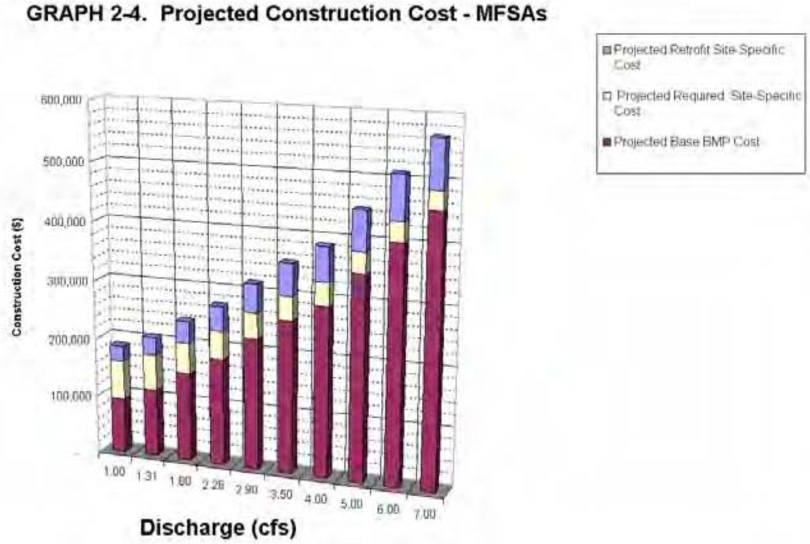
Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for MFSAs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an MFSA unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the MFSA is constructed using a process other than retrofit of an existing facility.

TABLE 2-B. PROJECTED CONSTRUCTION COSTS - MFSAs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Media Filter (Austin Sand Filter)												
	Typical Site with Indicated Discharge	94,219	66,349	25,947	186,515		1.00		94,219	66,349	25,947	186,515
112204		117,043	59,878	30,319	207,240	0.80	1.31	0.09	89,551	45,813	23,197	158,561
074202		151,691	52,965	36,522	241,178	1.50	1.80	0.09	84,273	29,425	20,290	133,988
1112203		182,405	48,541	41,690	272,636	2.70	2.26	0.19	80,710	21,478	18,447	120,635
074203		223,241	44,116	46,197	315,554	1.80	2.90	0.18	76,980	15,212	16,620	108,812
074204		259,981	41,048	53,767	354,797	2.80	3.50	0.18	74,280	11,728	15,362	101,371
		289,686	39,000	58,109	386,795		4.00		72,421	9,750	14,527	96,699
		347,092	35,803	66,162	449,056		5.00		69,418	7,161	13,232	89,811
		402,343	33,386	73,563	509,293		6.00		67,057	5,564	12,261	84,882
		455,866	31,471	80,463	567,800		7.00		65,124	4,496	11,495	81,114



GRAPH 2-3. Projected Unit Cost - MFSAs



GRAPH 2-4. Projected Construction Cost - MFSAs

3. Media Filter (Delaware Sand Filter) – Projected Construction Cost Analysis

This section projects construction costs for the Media Filter - Delaware Sand Filter (MFSD) BMP type. Adjusted cost data for the MFSD device is shown in Table 3-A, listed in ascending order by water quality design size. Water quality design units for the MFSD are specified by discharge in cfs.

Only one MFSD was constructed as part of the Pilot Program. For this reason, the data for this one installation, and data derived from the MFSA analysis, were used to generate sufficient data to project construction costs for the MFSD. Since the MFSD and MFSA are similar in general design and function, it is assumed that construction of the two devices is likewise similar.

The Base BMP Cost data for the MFSD in Table 3-A were generated as follows:

- The Base BMP Cost for the one Pilot Program installation is included. In Table 3-A, this is identified by its WQ ID number.
- The MFSA Base BMP Cost Curve (Graph 2-2) was adjusted to pass through the MFSD Base BMP Unit Cost for the Pilot Program installation. This resulted in an MFSA Curve Adjustment Factor of 1.07 (shown at the bottom of Table 3-A). This factor was then applied to the costs derived from the MFSA Base BMP Cost Curve for each discharge. The resulting Base BMP Costs are identified in Table 3-A by their discharge sizes in the WQ ID No. column.
- The "average" of the Base BMP Cost for all MFSDs constructed for the Pilot Program was calculated. In Table 3-A, this is identified as "Avg MFSD" in the WQ ID No. column. Since there was only one installation for the BMP type, the average Base BMP Cost is the same as the Base BMP Cost for the one installed BMP.

The Required Site-Specific Cost data for the MFSD in Table 3-A were generated as follows:

- The known value for the one Pilot Program installation is shown.
- The cost curve equation for the MFSA Required Site-Specific Costs (Graph 2-2) is used to derive the values for the other MFSD water quality design discharges, including Avg MFSD. It is assumed that the required site-specific costs would be similar for the MFSD and MFSA and, therefore, the adjustment factor is 1.00 (no adjustment).

The Retrofit Site-Specific Cost data for the MFSD in Table 3-A were generated as follows:

- The known value for the one Pilot Program installation is shown.
- The cost curve equation for the MFSA Retrofit Site-Specific Costs (Graph 2-2) is used to derive the values for the other MFSD water quality design discharges, including the Avg MFSD. It is assumed that the retrofit site-specific costs would be similar for the MFSD and MFSA and, therefore, the adjustment factor is 1.00 (no adjustment).

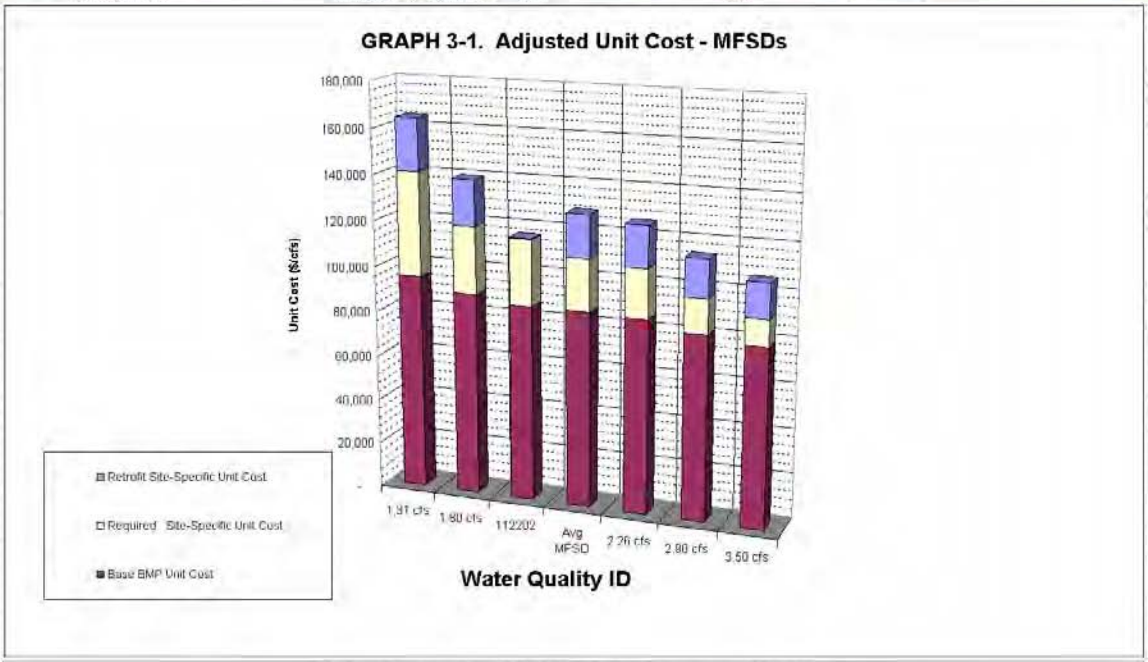
For the data in Table 3-A, the Total Adjusted Unit Costs ranged from $106,236 to 164,426 per cfs, as shown in Graph 3-1.

For all MFSDs, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. For the five MFSDs with the largest design discharge, the Required Site-Specific Unit Cost was the second most costly category. For the two MFSDs with the smallest design discharge, the Retrofit Site-Specific Costs were the second most costly category.

The cost curves for each category are shown in Graph 3-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 3-A. ADJUSTED UNIT COST - MFSD

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Media Filter (Delaware Sand Filter)													
1.31 cfs			124,709	59,878	30,319	214,905		1.31		95,416	45,813	23,197	164,426
1.80 cfs			161,626	52,965	36,522	251,113		1.80		89,792	29,425	20,290	139,507
112202	MFSD	Escondido Maint. Station	186,933	62,800	576	250,309	0.80	2.15	0.30	86,784	29,155	267	116,207
Avg MFSD		Average	186,933	49,443	40,542	276,917		2.15		86,784	22,954	18,822	128,560
2.26 cfs			194,352	48,541	41,690	284,583		2.26		85,996	21,478	18,447	125,922
2.90 cfs			237,862	44,116	48,197	330,175		2.90		82,021	15,212	16,620	113,853
3.50 cfs			277,009	41,048	53,767	371,824		3.50		79,145	11,728	15,362	106,236
	MFSA Curve Adjustment Factor		1.07	1.00	1.00								
	Average MFSD		$ 186,933	$ 62,800	$ 576			2.15					



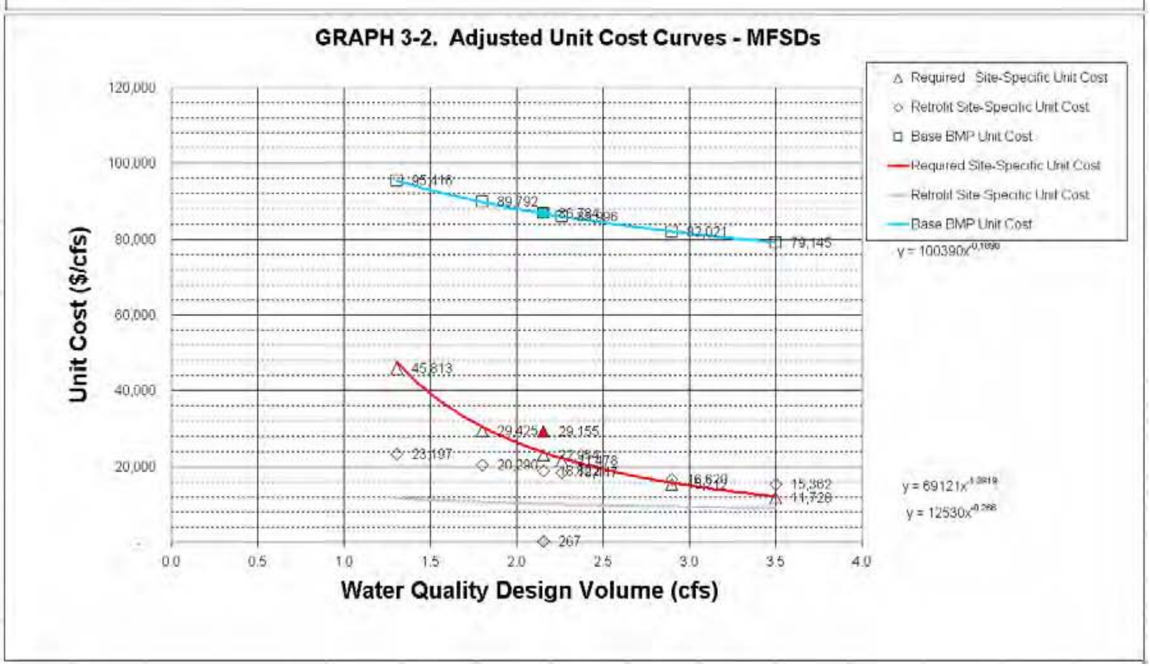


Table 3-B shows projected cost data derived using the cost curve equations from Graph 3-2 for eight different water quality design discharges; the one associated with the Pilot Program installation, and seven additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the eight water quality design discharges in the table, the Total Projected Unit Costs ranged from $81,462 to 182,041, as shown in Graph 3-3. The graph indicates that total unit cost decreases as design discharge increases. For all eight water quality design discharges, the Projected Base BMP Unit Cost was the largest component of the total projected unit cost. For the five projections with the smallest design discharge, the Projected Required Site-Specific Unit Costs were the second most costly category. For the three largest design discharges, the Projected Retrofit Site-Specific Unit Costs were the second most costly category.

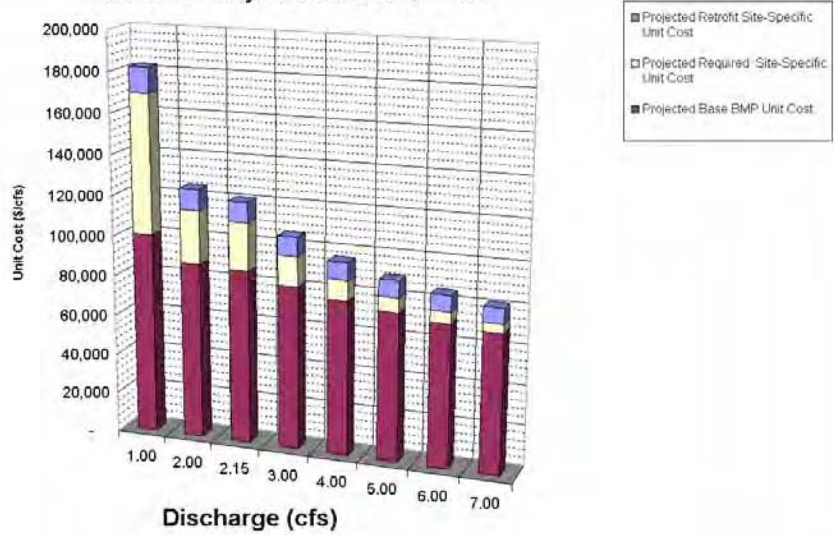
Graph 3-4 graphically represents the Total Projected Construction Cost data from Table 3-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing an MFSD as the water quality design discharge increases. The graph also shows that costs for Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design discharge.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for MFSDs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an MFSD unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the MFSD is constructed using a process other than retrofit of an existing facility.

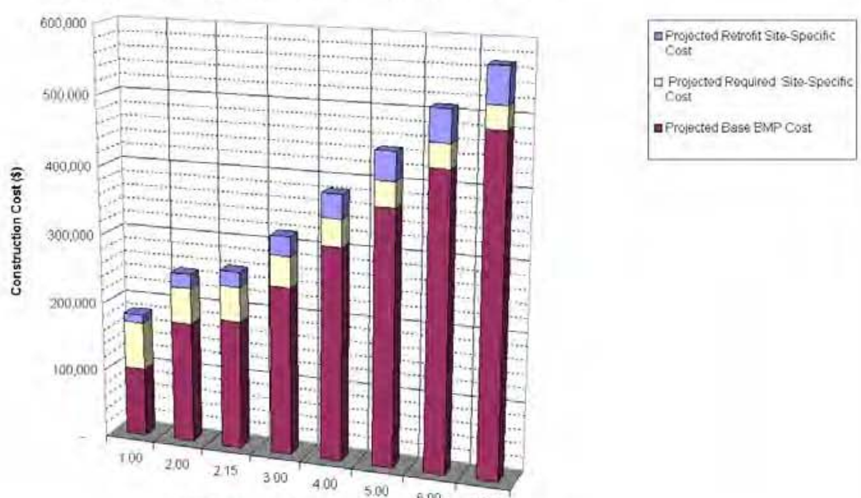
TABLE 3-B. PROJECTED CONSTRUCTION COSTS - MFSDs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Media Filter (Delaware Sand Filter)												
	Typical Site with Indicated Discharge	100,390	69,121	12,530	182,041		1.00		100,390	69,121	12,530	182,041
		176,029	52,679	20,840	249,549		2.00		88,015	26,339	10,420	124,774
112202		186,933	51,169	22,007	260,109	0.80	2.15	0.30	86,784	23,756	10,217	120,756
		244,486	44,939	28,065	317,490		3.00		81,495	14,980	9,355	105,830
		308,659	40,148	34,663	383,470		4.00		77,165	10,037	8,666	95,868
		369,825	36,786	40,831	447,442		5.00		73,965	7,357	8,166	89,488
		428,695	34,249	46,678	509,623		6.00		71,449	5,708	7,780	84,937
		485,723	32,242	52,270	570,235		7.00		69,389	4,606	7,467	81,462

GRAPH 3-3. Projected Unit Cost - MFSDs



GRAPH 3-4. Projected Construction Cost - MFSDs



4. Multi-Chambered Treatment Train – Projected Construction Cost Analysis

This section projects construction costs for the Multi-Chambered Treatment Train (MCTT) BMP type. Adjusted cost data for the MCTT device is shown in Table 4-A, listed in ascending order by water quality design size. Water quality design units for the MCTT are specified by discharge in cfs.

Of the three MCTTs constructed as part of the Pilot Program, only two had data available for this analysis. For this reason, the data for the two installations, and data derived from the MFSA analysis, were used to generate sufficient data to project construction costs for the MCTT. Since the MCTT and MFSA are similar in function, it is assumed that construction of the two devices is likewise similar.

The Base BMP Cost data for the MCTT in Table 4-A were generated as follows:

- The Base BMP Cost for the two Pilot Program installations is included. In Table 4-A, these are identified by WQ ID number.
- The MFSA Base BMP Cost Curve (Graph 2-2) was adjusted to pass through the average of the two MCTT Base BMP Unit Costs for the Pilot Program installations. This resulted in an MFSA Curve Adjustment Factor of 1.45 (shown at the bottom of Table 4-A). This factor was then applied to the costs derived from the MFSA Base BMP Cost Curve for each discharge. The resulting Base BMP Costs are identified in Table 4-A by their discharge sizes in the WQ ID No. column.
- The average of the Base BMP Cost for the two MCTTs constructed for the Pilot Program was calculated. In Table 4-A, this is identified as "Avg MCTT" in the WQ ID No. column.

The Required Site-Specific Cost data for the MCTT in Table 4-A were generated as follows:

- The known values for the two Pilot Program installations are included.
- The cost curve equation for the MFSA Required Site-Specific Costs (Graph 2-2) is used to derive the values for the other MCTT water quality design discharges, including the Avg MCTT. It is assumed that the required site-specific costs would be the similar for the MCTT and MFSA and, therefore, the adjustment factor is 1.00 (no adjustment).

The Retrofit Site-Specific Cost data for the MCTT in Table 4-A were generated as follows:

- The known values for the two Pilot Program installations are included.
- The cost curve equation for the MFSA Retrofit Site-Specific Costs (Graph 2-2) is used to derive the values for the other MCTT water quality design discharges, including the Avg MCTT. It is assumed that the retrofit site-specific costs would be the similar for the MCTT and MFSA and, therefore, the adjustment factor is 1.00 (no adjustment).

For the data in Table 4-A, the Total Adjusted Unit Costs ranged from $135,082 to $199,203 per cfs, as shown in Graph 4-1.

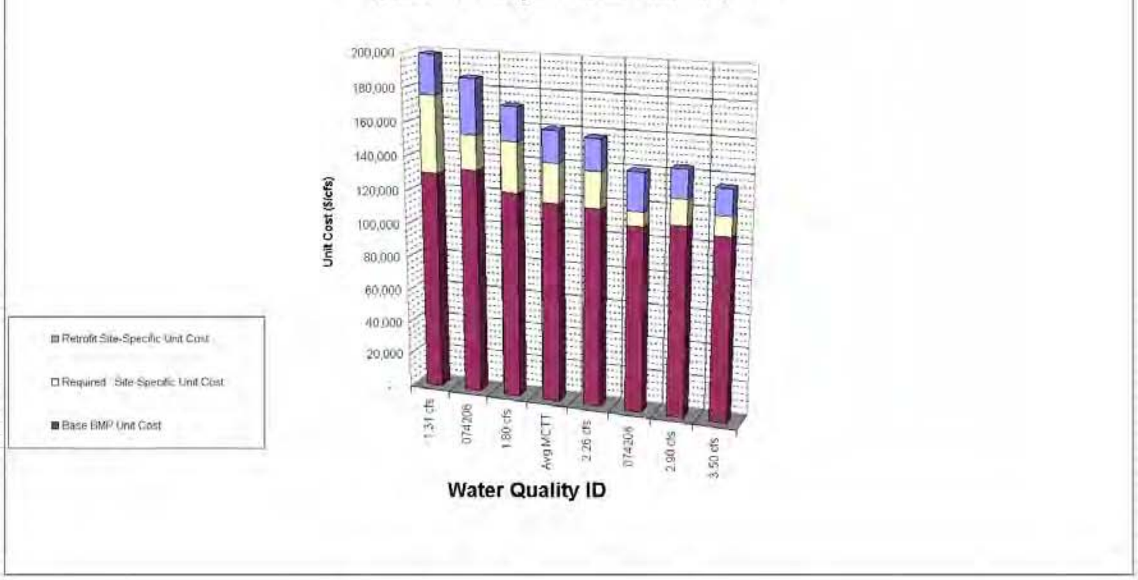
For all MCTTs, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. Generally, for the MCTTs with the smallest design discharge, the Required Site-Specific Unit Cost was the second most costly category. For the MCTTs with the larger design discharges, the Retrofit Site-Specific Cost tended to be the second most costly category.

The cost curves for each category, are shown in Graph 4-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 4-A. ADJUSTED UNIT COST - MCTTs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/cfs)	Required Site-Specific Unit Cost ($/cfs)	Retrofit Site-Specific Unit Cost ($/cfs)	Total Adjusted Unit Cost ($/cfs)
Multi-Chambered Treatment Train													
1.31 cfs			170,162	59,878	30,319	260,358		1.31		130,192	45,813	23,197	199,203
074206		Via Verde Park & Ride	213,493	33,492	51,680	298,665	1.10	1.60	0.10	133,433	20,933	32,300	186,666
1.80 cfs			220,535	52,965	36,522	310,021		1.80		122,519	29,425	20,290	172,234
Avg MCTT		Average	254,681	49,478	40,498	344,657		2.15		118,456	23,013	18,836	160,305
2.26 cfs			265,188	48,541	41,690	355,419		2.26		117,340	21,478	18,447	157,265
074208		Lakewood Park & Ride	295,869	21,934	61,321	379,125	1.93	2.70	0.14	109,581	8,124	22,711	140,417
2.90 cfs			324,556	44,116	48,197	416,869		2.90		111,916	15,212	16,620	143,748
3.50 cfs			377,971	41,048	53,767	472,787		3.50		107,992	11,728	15,362	135,082
	MFSA Curve Adjustment Factor		1.45	1.00	1.00								
	Average MCTT		$ 254,681	$ 27,713	$ 56,500			2.15					

GRAPH 4-1. Adjusted Unit Cost - MCTTs



GRAPH 4-2. Adjusted Unit Cost Curves - MCTTs

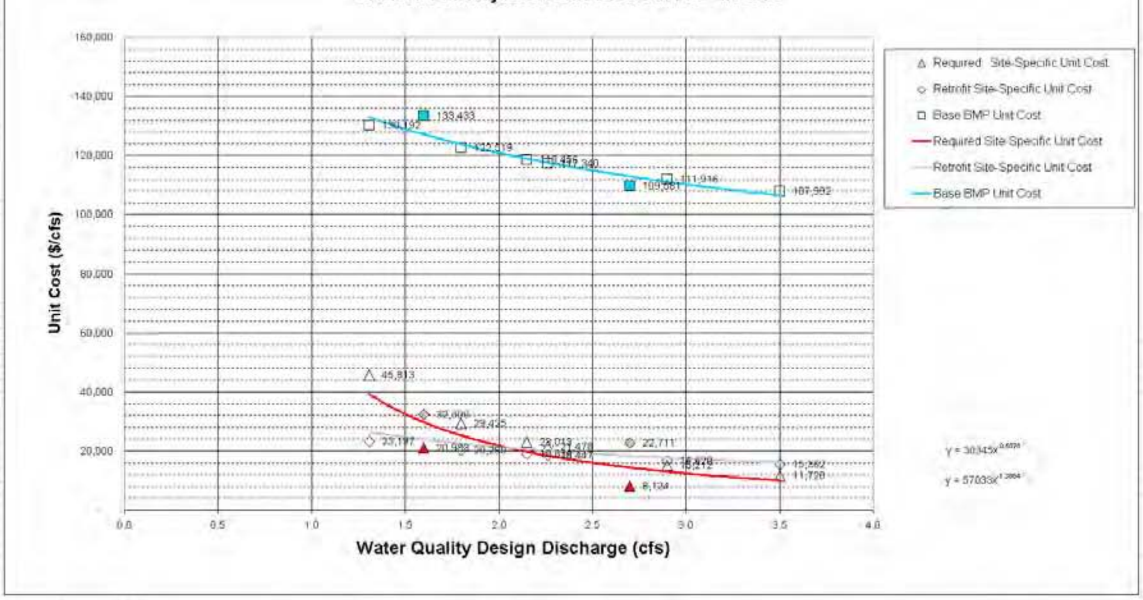


Table 4-B shows projected cost data derived using the cost curve equations from Graph 4-2 for nine different water quality design discharges; the two associated with the Pilot Program installations, and seven additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the nine water quality design discharges in the table, the Total Projected Unit Costs ranged from $106,255 to $228,735, as shown in Graph 4-3. The graph indicates that total unit cost decreases as design discharge increases. For all nine water quality design discharges, the Projected Base BMP Unit Cost was the largest component of the total projected unit cost. For the three projections with the smallest design discharge, the Projected Required Site-Specific Unit Costs were the second most costly category. For the six largest design discharges, the Projected Retrofit Site-Specific Unit Costs were the second most costly category.

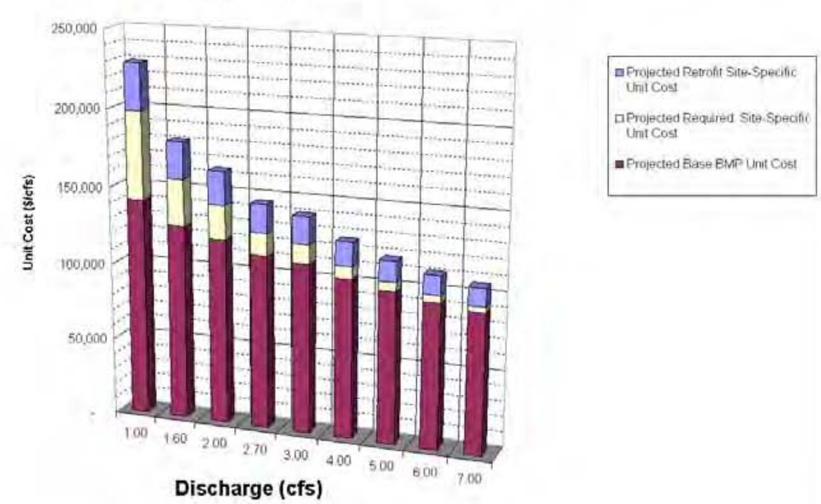
Graph 4-4 graphically represents the Total Projected Construction Cost data from Table 4-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing an MCTT as the water quality design discharge increases. The graph also shows that costs for Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design discharge.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for MCTTs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an MCTT unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the MCTT is constructed using a process other than retrofit of an existing facility.

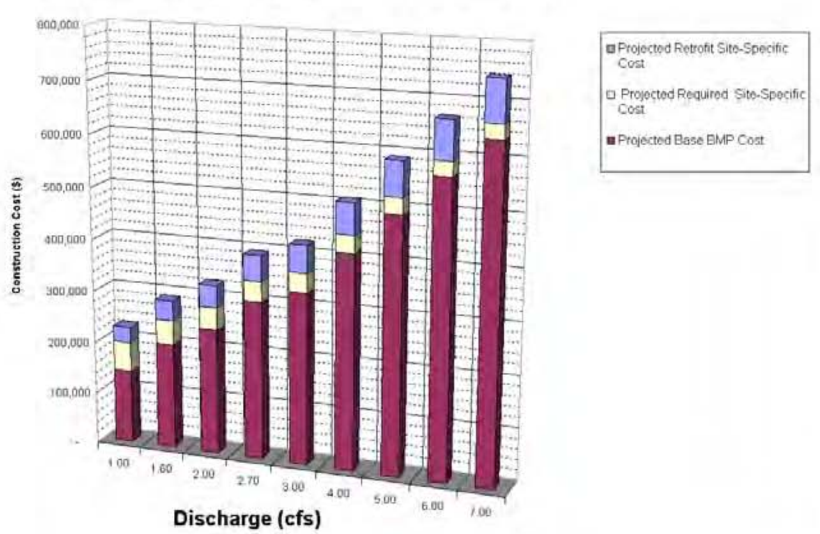
TABLE 4-B. PROJECTED CONSTRUCTION COSTS - MCTTs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Multi-Chamber Treatment Train												
	Typical Site with Indicated Discharge	141,357	57,033	30,345	228,735		1.00		141,357	57,033	30,345	228,735
074206		203,408	47,561	38,247	289,216	1.10	1.60	0.10	127,130	29,726	23,904	180,760
		241,771	43,632	42,689	328,093		2.00		120,886	21,816	21,344	164,046
074208		305,016	38,855	49,487	393,358	1.93	2.70	0.14	112,969	14,391	18,328	145,688
		330,942	37,305	52,122	420,369		3.00		110,314	12,435	17,374	140,123
		413,516	33,380	60,054	506,950		4.00		103,379	8,345	15,013	126,738
		491,507	30,623	67,029	589,158		5.00		98,301	6,125	13,406	117,832
		566,030	28,540	73,324	667,895		6.00		94,338	4,757	12,221	111,316
		637,789	26,889	79,107	743,785		7.00		91,113	3,841	11,301	106,255

GRAPH 4-3. Projected Unit Cost - MCTTs



GRAPH 4-4. Projected Construction Cost - MCTTs



5. Media Filter (StormFilter) – Projected Construction Cost Analysis

This section projects construction costs for the Media Filter – StormFilter (MFSTF) BMP type. Adjusted cost data for the MFSTF device is shown in Table 5-A, listed in ascending order by water quality design size. Water quality design units for the MFSTF are specified by discharge in cfs.

There was only one MFSTF constructed as part of the Pilot Program. For this reason, the data for this one installation, and data derived from the MFSA analysis, were used to generate sufficient data to project construction costs for the MFSTF. Since the MFSTF and MFSA are similar in function, it is assumed that construction of the two devices is likewise similar.

The Base BMP Cost data for the MFSTF in Table 5-A were generated as follows:

- The Base BMP Cost for the one Pilot Program installation is included. In Table 5-A, this is identified by WQ ID number.
- The MFSA Base BMP Cost Curve (Graph 2-2) was adjusted to pass through the MFSTF Base BMP Unit Cost for the Pilot Program installation. This resulted in an MFSA Curve Adjustment Factor of 1.22 (shown at the bottom of Table 5-A). This factor was then applied to the costs derived from the MFSA Base BMP Cost Curve for each discharge. The resulting Base BMP Costs are identified in Table 5-A by their discharge sizes in the WQ ID No. column.
- The "average" of the Base BMP Cost for the MFSTF constructed for the Pilot Program was calculated. Since there was only one installation for the BMP type, the average Base BMP Cost is the same as the Base BMP Cost for the one installed BMP. In Table 5-A, this is identified as "Avg MCTT" in the WQ ID No. column.

The Required Site-Specific Cost data for the MFSTF in Table 5-A were generated as follows:

- The known value for the Pilot Program installation is included.
- The cost curve equation for the MFSA Required Site-Specific Costs (Graph 2-2) is used to derive the values for the other MFSTF water quality design discharges, including the Avg MFSTF. It is assumed that the required site-specific costs would be the similar for the MFSTF and MFSA and, therefore, the adjustment factor is 1.00 (no adjustment).

The Retrofit Site-Specific Cost data for the MFSTF in Table 5-A were generated as follows:

- The known value for the Pilot Program installation is included.
- The cost curve equation for the MFSA Retrofit Site-Specific Costs (Graph 2-2) is used to derive the values for the other MFSTF water quality design discharges, including the Avg MFSTF. It is assumed that the retrofit site-specific costs would be the similar for the MFSTF and MFSA and, therefore, the adjustment factor is 1.00 (no adjustment).

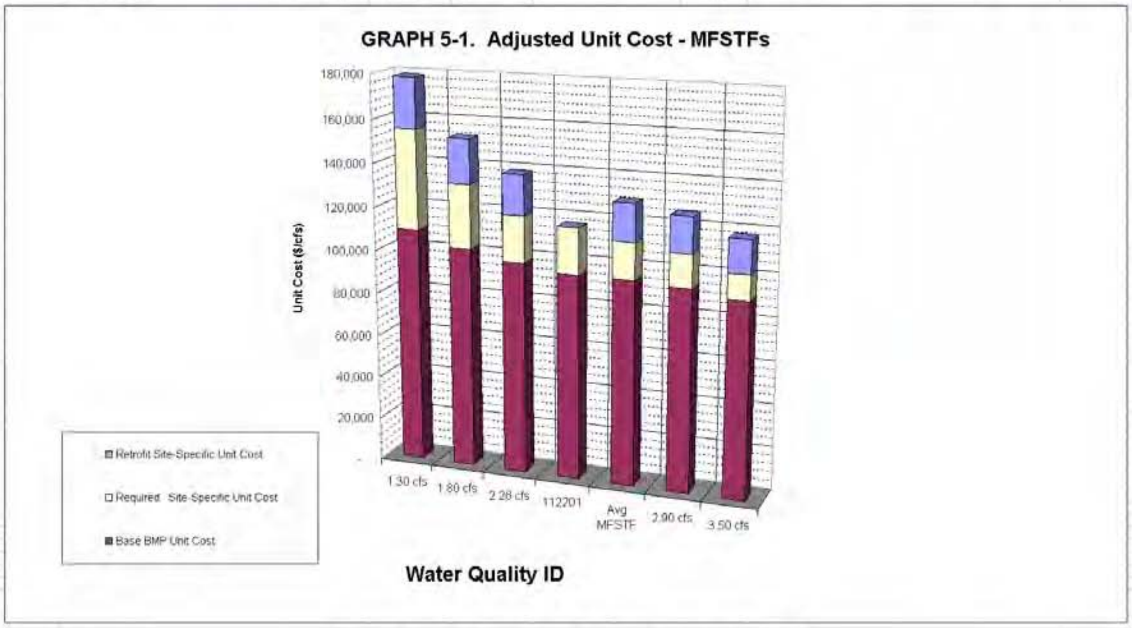
For the data in Table 5-A, the Total Adjusted Unit Costs ranged from \$117,667 to \$178,713 per cfs, as shown in Graph 5-1.

For all MFSTFs, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. Generally, for the four MFSTFs with the smallest design discharge, the Required Site-Specific Unit Cost was the second most costly category. For the three MFSTFs with the largest design discharges, the Retrofit Site-Specific Cost was the second most costly category.

The cost curves for each category, are shown in Graph 5-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 5-A. ADJUSTED UNIT COST - MFSTF

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Media Filter (Stormfilter)													
1.30 cfs			142,101	60,001	30,224	232,327		1.30	0.30	109,308	46,155	23,249	178,713
1.80 cfs			184,970	52,965	36,522	274,457		1.80	0.30	102,761	29,425	20,290	152,476
2.26 cfs			222,423	48,541	41,690	312,654		2.26	0.30	98,417	21,478	18,447	138,342
112201	MFSTF	Kearny Mesa Maint. Station	255,670	57,029	1	312,700	1.00	2.68	-	95,257	21,246	0	116,505
Avg MFSTF			255,670	45,445	46,075	347,190		2.68	0.30	95,257	16,932	17,167	129,355
2.90 cfs			272,217	44,116	48,197	364,530		2.90	0.30	93,868	15,212	16,620	125,700
3.50 cfs			317,018	41,048	53,787	411,833		3.50	0.30	90,577	11,728	15,362	117,667
	MFSA Curve Adjustment Factor		1.22	1.00	1.00								
	Average MFSTF		$ 255,670	$ 57,029	$ 1			2.68					



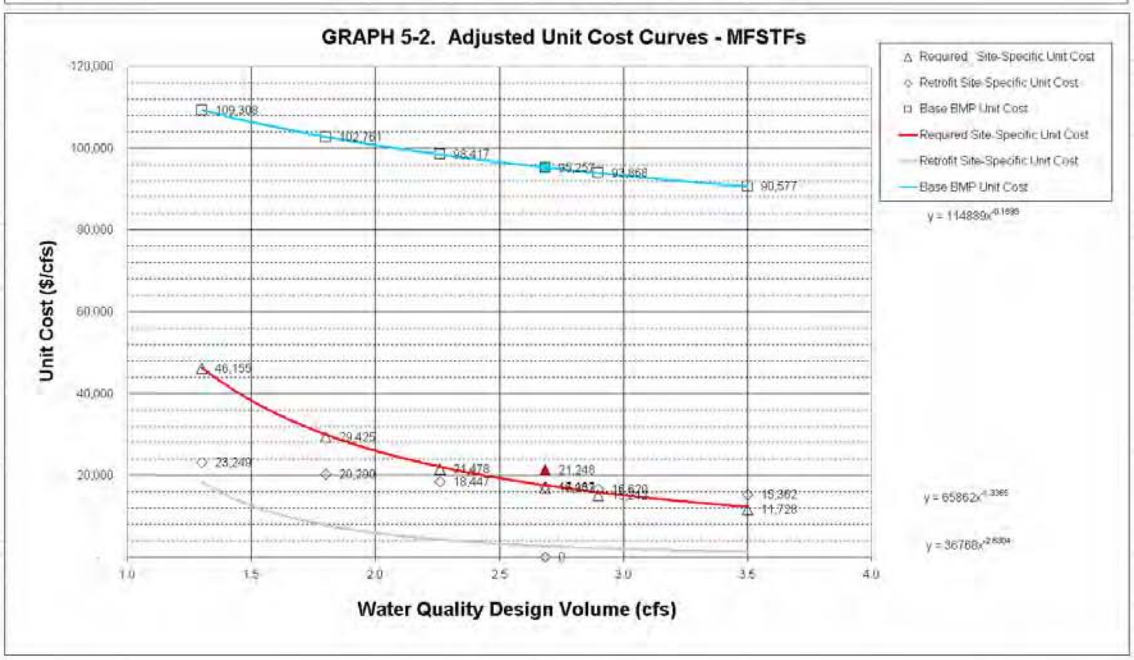


Table 5-B shows projected cost data derived using the cost curve equations from Graph 5-2 for nine different water quality design discharges; the one associated with the Pilot Program installations, and eight additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the nine water quality design discharges in the table, the Total Projected Unit Costs ranged from \$84,519 to \$217,519, as shown in Graph 5-3. The graph indicates that total unit cost decreases as design discharge increases. For all nine water quality design discharges, the Projected Base BMP Unit Cost was the largest component of the total projected unit cost. For all design discharges, Projected Required Site-Specific Unit Costs were the second most costly category.

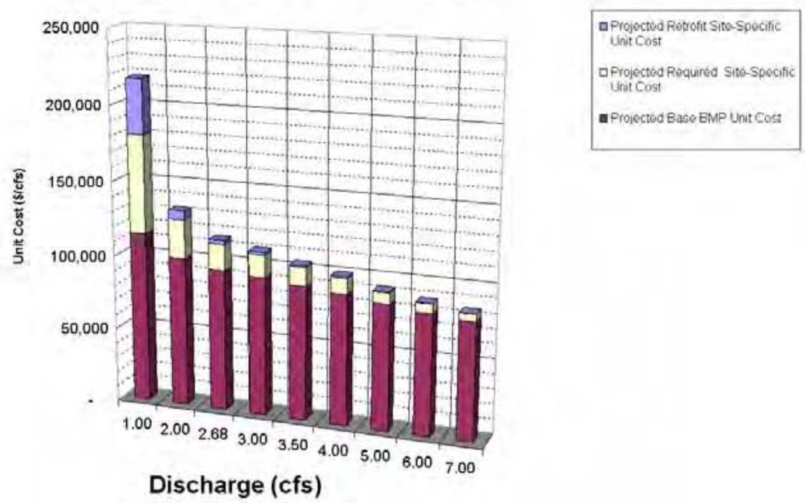
Graph 5-4 graphically represents the Total Projected Construction Cost data from Table 5-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing an MFSTF as the water quality design discharge increases. The graph also shows that costs for Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design discharge size.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for MFSTFs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an MFSTF unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the MFSTF is constructed using a process other than retrofit of an existing facility.

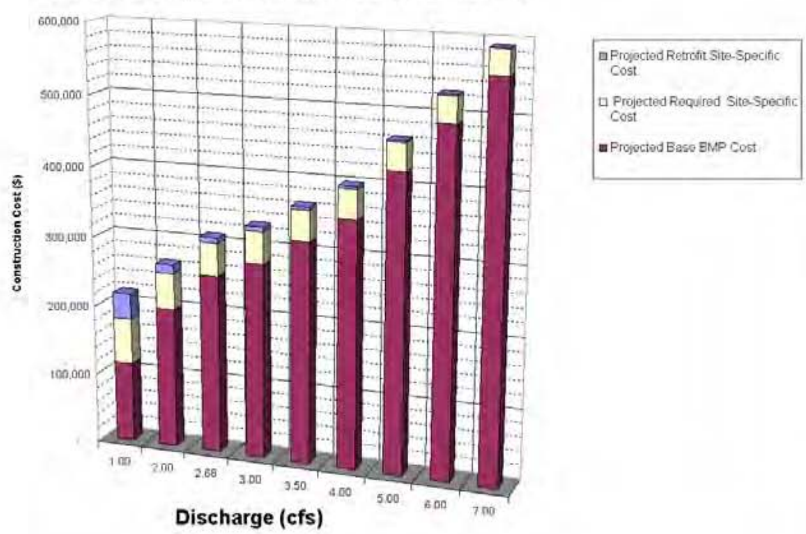
TABLE 5-B. PROJECTED CONSTRUCTION COSTS - MFSTFs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Media Filter (Stormfilter)												
	Typical Site with Indicated Discharge	114,889	65,862	36,768	217,519		1.00		114,889	65,862	36,768	217,519
		201,453	52,160	11,876	265,489		2.00		100,726	26,080	5,938	132,744
112201		255,669	47,244	7,352	310,265	1.00	2.68	-	95,257	17,602	2,739	115,598
		279,796	45,508	6,132	331,436		3.00		93,265	15,169	2,044	110,479
		317,017	43,207	4,769	364,993		3.50		90,576	12,345	1,363	104,284
		353,238	41,309	3,836	398,383		4.00		88,310	10,327	959	99,596
		423,237	38,321	2,666	464,224		5.00		84,647	7,664	533	92,845
		490,610	36,040	1,980	528,631		6.00		81,768	6,007	330	88,105
		555,875	34,218	1,540	591,633		7.00		79,411	4,888	220	84,519

GRAPH 5-3. Projected Unit Cost - MFSTFs



GRAPH 5-4. Projected Construction Cost - MFSTFs



6. Biofiltration Swale – Projected Construction Cost Analysis

This section projects construction costs for the Biofiltration Swale (BSW) BMP type. Table 6-A presents the adjusted unit costs for six BSW devices constructed as part of the Caltrans Pilot Program, listed in ascending order by water quality design size. Water quality design units for the BSW are specified by discharge in cfs.

For the six BSW installations analyzed from the Pilot Program, the Total Adjusted Unit Costs ranged from $46,772 to 559,493 per cfs, as shown in Graph 6-1.

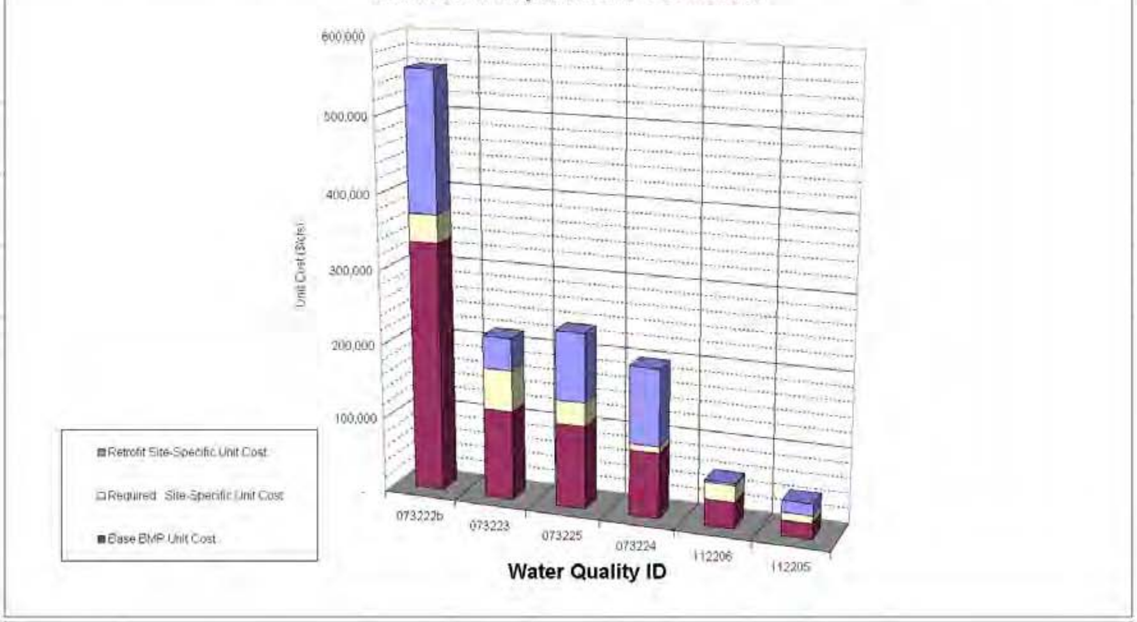
For five installations, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. For one installation, the Retrofit Site-Specific Cost was the most costly category. For four installations, the Retrofit Site-Specific Unit Cost was the second most costly category, with the Required Site-Specific Cost the second most costly category for the remaining two installations.

The cost curves for each category, are shown in Graph 6-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 6-A. ADJUSTED UNIT COST - BSW

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
						Bio-Swale							
073222b	BSW	I-605/SR 91	23,441	2,609	13,114	39,165	0.80	0.07	-	334,875	37,276	187,342	559,493
073223	BSW	Cerritos Maint. Station	15,533	7,234	5,574	28,341	0.40	0.13	-	119,485	55,646	42,877	218,007
073225	BSW	I-605/Del Amo Ave	23,529	6,569	19,272	49,370	0.70	0.21	-	112,041	31,282	91,770	235,093
073224	BSW	I-5/I-605	22,842	2,419	26,552	51,814	0.65	0.26	-	87,854	9,305	102,124	199,283
112206	BSW	I-5/Palomar Airport Rd.	58,920	36,828	4,740	100,489	2.30	1.66	-	35,494	22,186	2,856	60,535
112205	BSW	SR 78/Melrose Dr	36,312	18,322	26,890	81,524	2.30	1.74	-	20,833	10,513	15,427	46,772

GRAPH 6-1. Adjusted Unit Cost - BSWs



GRAPH 6-2. Adjusted Unit Cost Curves - BSWs

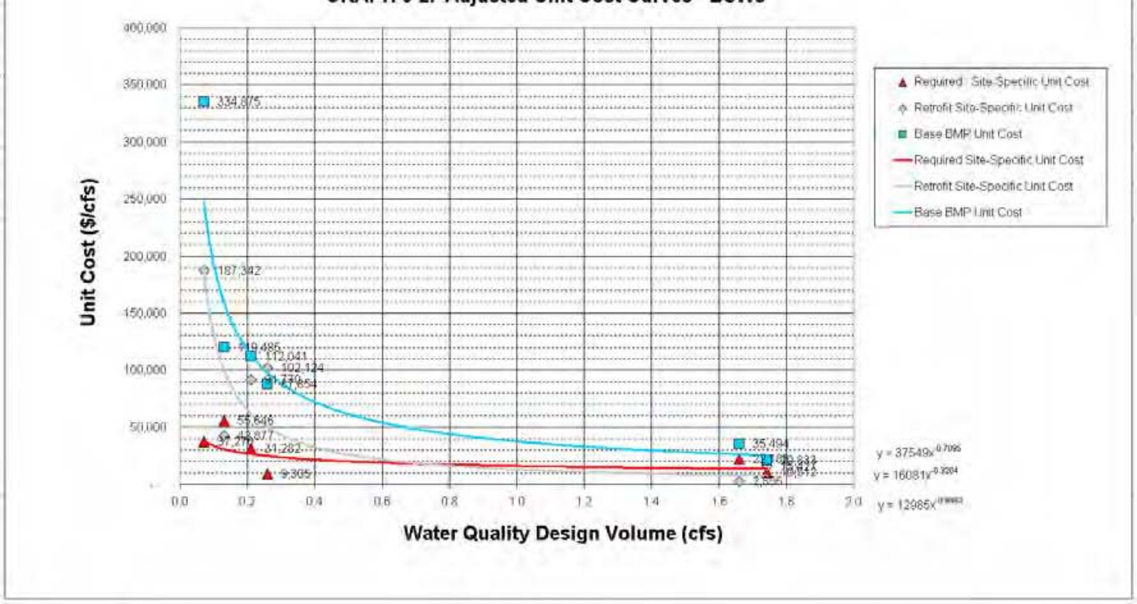


Table 6-B shows projected cost data derived using the cost curve equations from Graph 6-2 for 13 different water quality design discharges; the six associated with the Pilot Program installations, and seven additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the 13 water quality design discharges in the table, the Total Projected Unit Costs ranged from \$19,919 to \$470,549, as shown in Graph 6-3. The graph shows that total unit cost decreases as design discharge increases. For all 13 water quality design discharges, the Projected Base BMP Unit Cost was the largest component of the total projected unit cost. For the four projections with the smallest design discharge, the Projected Retrofit Site-Specific Unit Costs were the second most costly category. For the nine largest design discharges, the Projected Required Site-Specific Unit Costs were the second most costly category.

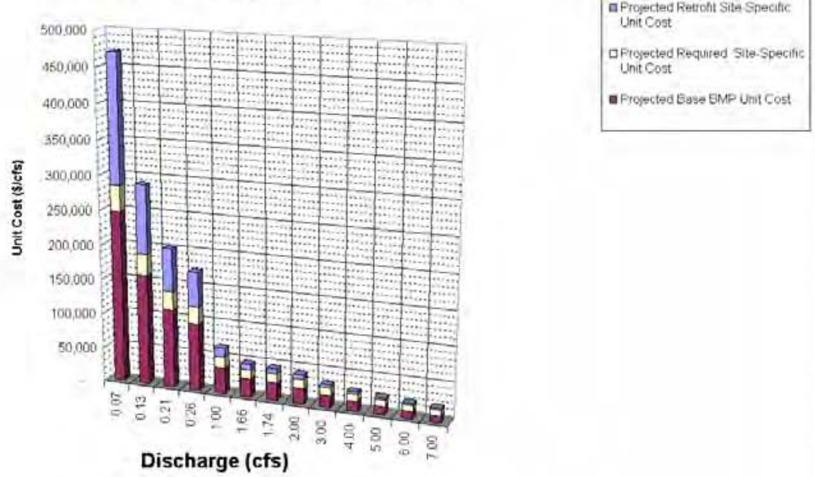
Graph 6-4 graphically represents the Total Projected Construction Cost data from Table 6-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing a BSW as the water quality design discharge increases. The graph also shows that costs for Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design discharge.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for BSWs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of a BSW unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the BSW is constructed using a process other than retrofit of an existing facility.

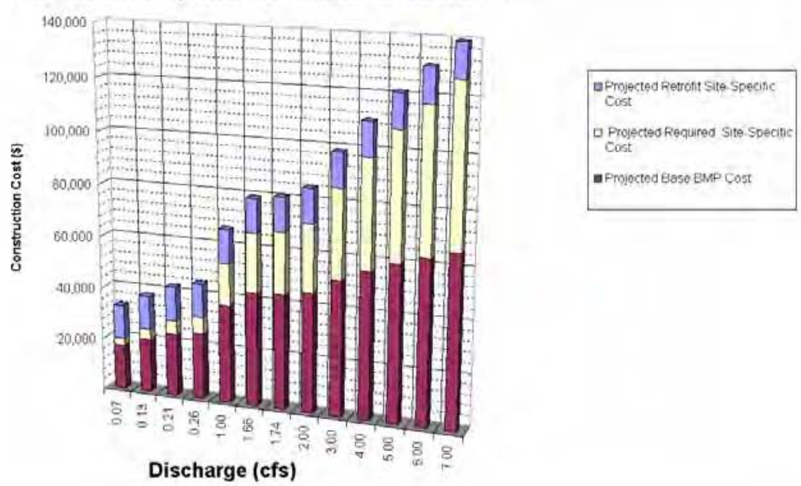
TABLE 6-B. PROJECTED CONSTRUCTION COSTS - BSWs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/cfs)	Projected Required Site-Specific Unit Cost ($/cfs)	Projected Retrofit Site-Specific Unit Cost ($/cfs)	Total Projected Unit Cost ($/cfs)
Bio-Swale												
073222b	Typical Site with Indicated Discharge	17,342	2,639	12,957	32,938	0.80	0.07	–	247,743	37,700	185,106	470,549
073223		20,759	4,019	12,964	37,742	0.40	0.13	–	159,682	30,918	99,722	290,321
073225		23,862	5,568	12,969	42,399	0.70	0.21	–	113,628	26,514	61,756	201,898
073224		25,389	6,438	12,971	44,798	0.65	0.26	–	97,651	24,760	49,889	172,299
		37,549	16,081	12,985	66,615		1.00		37,549	16,081	12,985	66,615
112206		43,505	22,693	12,990	79,189	2.30	1.66	–	26,208	13,671	7,825	47,704
112205		44,126	23,458	12,991	80,575	2.30	1.74	–	25,316	13,459	7,453	46,228
		45,925	25,757	12,992	84,674		2.00		22,962	12,878	6,496	42,337
		51,666	33,928	12,996	98,591		3.00		17,222	11,309	4,332	32,864
		56,169	41,255	12,999	110,423		4.00		14,042	10,314	3,250	27,606
		59,931	48,010	13,002	120,943		5.00		11,986	9,602	2,600	24,189
		63,190	54,343	13,004	130,537		6.00		10,532	9,057	2,187	21,756
		66,084	60,345	13,005	139,435		7.00		9,441	8,621	1,858	19,919

GRAPH 6-3. Projected Unit Cost - BSWs



GRAPH 6-4. Projected Construction Cost - BSWs



7. Biofiltration Strip – Projected Construction Cost Analysis

This section projects construction costs for the Biofiltration Strip (BSTRP) BMP type. Table 7-A presents the adjusted unit costs for three BSTRP devices constructed as part of the Caltrans Pilot Program, listed in ascending order by water quality design size. Water quality design units for the BSTRP are specified by discharge in cfs.

For the three BSTRP installations analyzed from the Pilot Program, the Total Adjusted Unit Costs ranged from $88,262 to $455,347 per cfs, as shown in Graph 7-1.

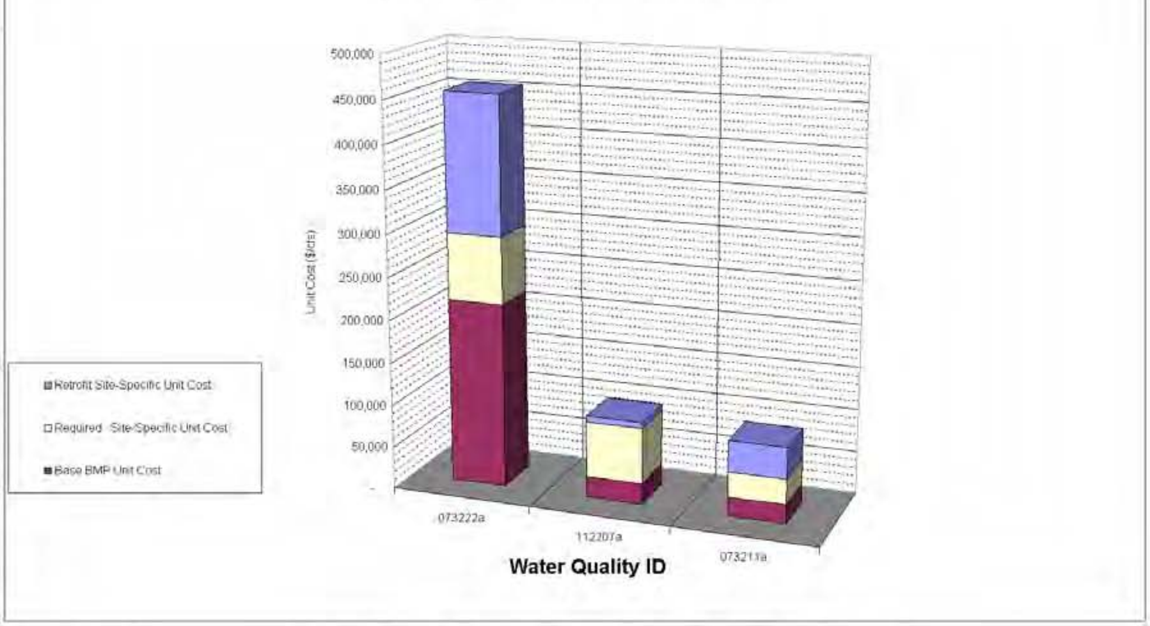
For one installation, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. For another, the Required Site-Specific Cost was the most costly category, while for the third installation, the Retrofit Site-Specific Costs were the greatest.

The cost curves for each category, are shown in Graph 7-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 7-A. ADJUSTED UNIT COSTS - BSTRP

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/cfs)	Required Site-Specific Unit Cost ($/cfs)	Retrofit Site-Specific Unit Cost ($/cfs)	Total Adjusted Unit Cost ($/cfs)
						Bio-Strip							
073222a	BSTRP	I-605/SR 91	30,319	10,883	22,547	63,749	0.47	0.14	-	216,567	77,733	161,047	455,347
112207a	BSTRP	Carlsbad Maint. Station (west)	14,810	38,966	4,486	58,261	2.40	0.60	-	24,683	64,943	7,476	97,102
073211a	BSTRP	Altadena Maint. Station	25,985	33,648	42,751	102,384	1.66	1.16	-	22,401	29,007	36,854	88,262

GRAPH 7-1. Adjusted Unit Cost -BSTRPs



GRAPH 7-2. Adjusted Unit Cost Curves - BSTRPs

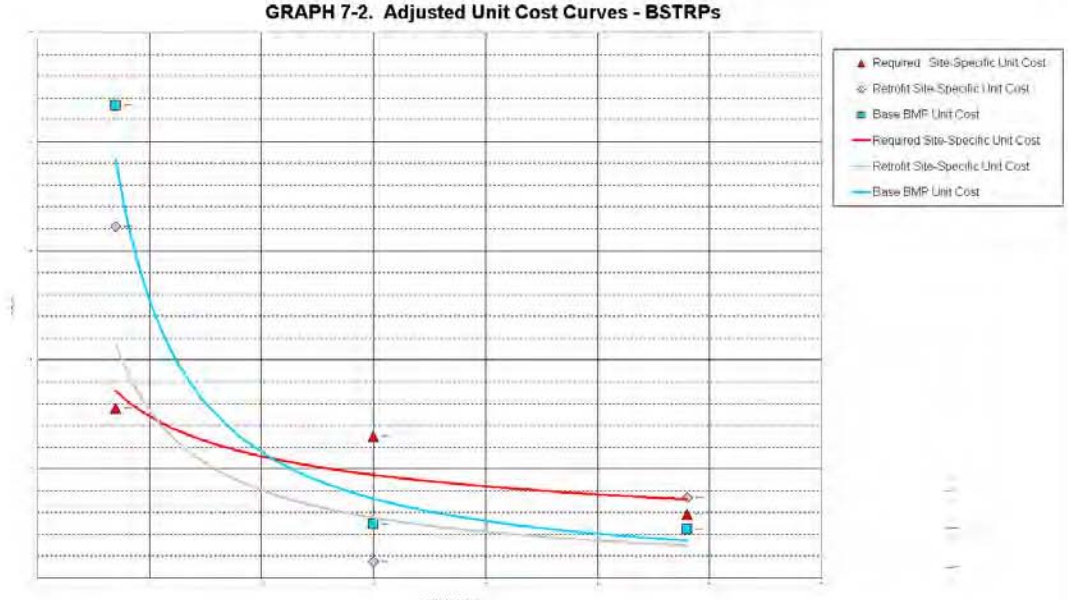


Table 7-B shows projected cost data derived using the cost curve equations from Graph 7-2 for 10 different water quality design discharges; the three associated with the Pilot Program installations, and seven additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the 10 water quality design discharges in the table, the Total Projected Unit Costs ranged from $22,294 to $384,774, as shown in Graph 7-3. The graph shows that total unit cost decreases as design discharge increases. For all but the smallest design discharge, the Projected Required Site-Specific Unit Cost was the largest component of the total projected unit cost.

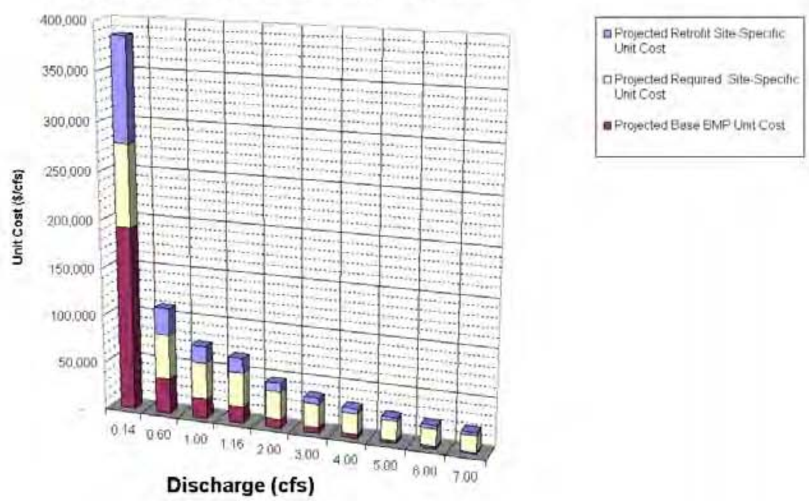
Graph 7-4 graphically represents the Total Projected Construction Cost data from Table 7-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing a BSTRP as the water quality design discharge increases.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for BSTRPs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of a BSTRPs unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the BSTRP is constructed using a process other than retrofit of an existing facility.

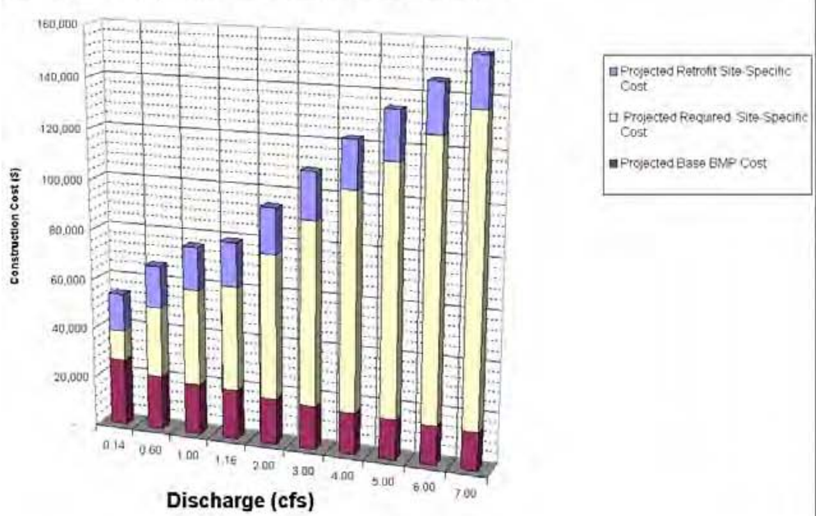
TABLE 7-B. PROJECTED CONSTRUCTION COSTS - BSTRPs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/cfs)	Projected Required Site-Specific Unit Cost ($/cfs)	Projected Retrofit Site-Specific Unit Cost ($/cfs)	Total Projected Unit Cost ($/cfs)
Bio-Strip												
073222a	Typical Site with Indicated Discharge	26,859	12,016	14,994	53,868	0.47	0.14	-	191,849	85,826	107,099	$384,774
112207a		21,841	28,368	16,595	66,804	2.40	0.60	-	36,402	47,280	27,658	$111,340
		20,312	38,352	17,196	75,860		1.00		20,312	38,352	17,196	$75,860
073211a		19,888	41,864	17,375	79,127	1.66	1.16	-	17,145	36,089	14,978	$68,213
		18,407	57,741	18,047	94,195		2.00		9,203	28,871	9,024	$47,098
		17,376	73,356	18,564	109,296		3.00		5,792	24,452	6,188	$36,432
		16,680	86,933	18,940	122,554		4.00		4,170	21,733	4,735	$30,638
		16,160	99,172	19,237	134,569		5.00		3,232	19,834	3,847	$26,914
		15,746	110,441	19,483	145,671		6.00		2,624	18,407	3,247	$24,278
		15,405	120,962	19,694	156,061		7.00		2,201	17,280	2,813	$22,294

GRAPH 7-3. Projected Unit Cost - BSTRPs



GRAPH 7-4. Projected Construction Cost - BSTRPs



8. Infiltration Basin – Projected Construction Cost Analysis

This section projects construction costs for the Infiltration Basin (IB) BMP type. Adjusted cost data for the IB device is shown in Table 8-A, listed in ascending order by water quality design size. Water quality design units for the IB are specified as volume in acre-ft.

Only two IBs were constructed as part of the Pilot Program. For this reason, the data for the two installations, and data derived from the EDB analysis, were used to generate sufficient data to project construction costs for the IB.

The Base BMP Cost data for the IB in Table 8-A were generated as follows:

- The Base BMP Cost for the two Pilot Program installations is included. In Table 8-A, these are identified by WQ ID number.
- The EBD Base BMP Cost Curve (Graph 1-2) was adjusted to pass through the average of the two IB Base BMP Unit Costs for the Pilot Program installations. This resulted in an EDB Curve Adjustment Factor of 0.79 (shown at the bottom of Table 8-A). This factor was then applied to the costs derived from the EDB Base BMP Cost Curve for each volume. The resulting Base BMP Costs are identified in Table 8-A by their volumes in the WQ ID No. column.
- The average of the Base BMP Cost for the two IBs constructed for the Pilot Program was calculated. In Table 8-A, this is identified as "Avg IB" in the WQ ID No. column.

The Required Site-Specific Cost data for the IB in Table 8-A were generated as follows:

- The known values for the two Pilot Program installations are included.
- The cost curve equation for the EDB Required Site-Specific Costs (Graph 1-2) is used to derive the values for the other IB water quality design volumes, including the Avg IB. It is assumed that the required site-specific costs would be the similar for the IB and EDB and, therefore, the adjustment factor is 1.00 (no adjustment).

The Retrofit Site-Specific Cost data for the IB in Table 8-A were generated as follows:

- The known values for the two Pilot Program installations are included.
- The cost curve equation for the EBD Retrofit Site-Specific Costs (Graph 1-2) is used to derive the values for the other IB water quality design volumes, including the Avg IB. It is assumed that the retrofit site-specific costs would be the similar for the IB and EDB and, therefore, the adjustment factor is 1.00 (no adjustment).

For the data in Table 8-A, the Total Adjusted Unit Costs ranged from $343,432 to $1,115,528 per acre-ft, as shown in Graph 8-1.

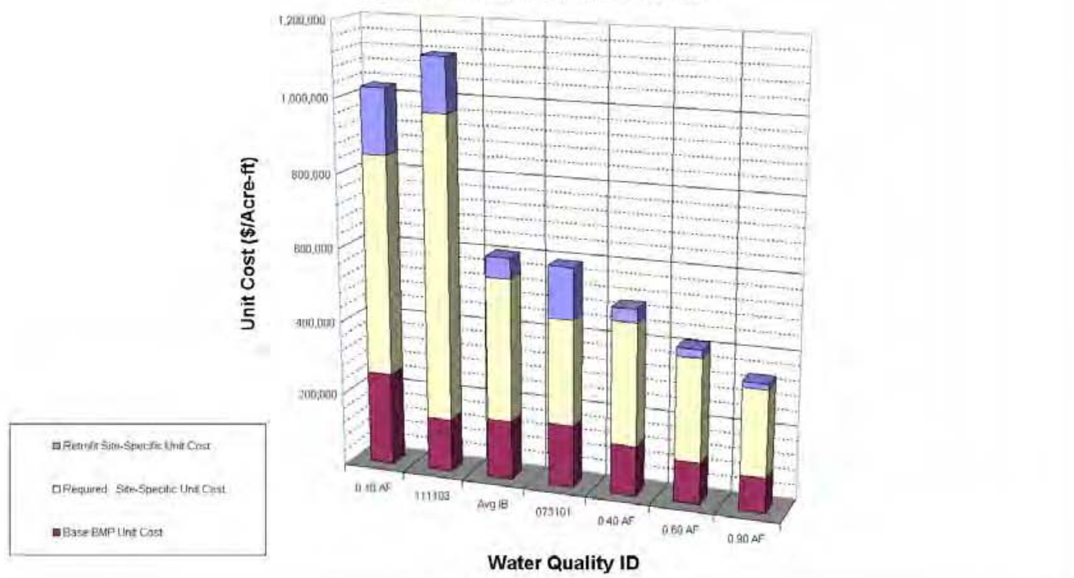
For all IBs, Required Site-Specific Unit Cost was the largest category of the total adjusted unit cost. For six of the seven design volumes, Base Unit Cost was the second most costly category.

The cost curves for each category, are shown in Graph 8-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design volume increases.

TABLE 8-A. ADJUSTED UNIT COSTS - IBs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Infiltration Basins													
0.10 AF			25,234	59,538	17,812	102,583			0.10	252,336	595,379	178,117	1,025,832
111103	IB	I-5/La Costa (west)	28,686	164,957	29,409	223,052	3.20	3.04	0.20	143,432	824,783	147,043	1,115,258
Avg IB		Average	44,083	106,644	15,489	166,217			0.28	160,302	387,797	56,325	604,424
073101	IB	I-605/SR 91	59,480	100,102	48,695	208,276	4.20	0.91	0.35	169,942	286,006	139,128	595,076
0.40 AF			54,202	132,343	14,708	201,253			0.40	135,505	330,857	36,771	503,133
0.60 AF			67,784	167,172	13,907	248,864			0.60	112,974	278,621	23,179	414,773
0.90 AF			84,770	211,168	13,150	309,088			0.90	94,189	234,631	14,611	343,432
	EDB Curve Adjustment Factor		0.79	1.00	1.00								
	Average IB		$ 44,083	$ 132,529	$ 39,052				0.28				

GRAPH 8-1. Adjusted Unit Cost - IBs



GRAPH 8-2. Adjusted Unit Cost Curves - IBs

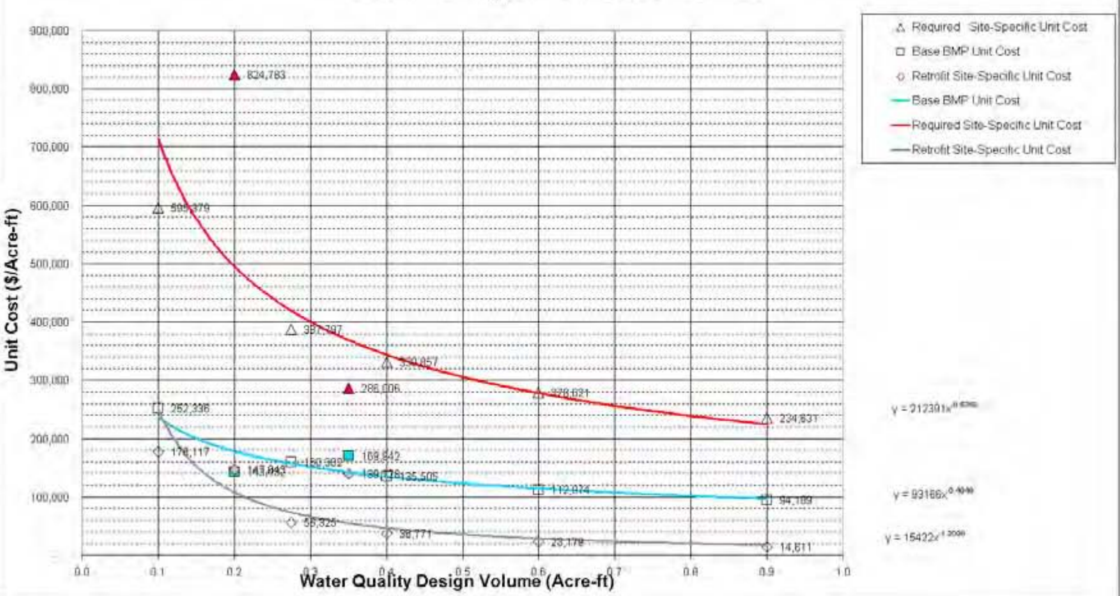


Table 8-B shows projected cost data derived using the cost curve equations from Graph 8-2 for 11 different water quality design volumes; the two associated with the Pilot Program installations, and nine additional volumes representing a typical range of values. The data are listed in ascending order by water quality design volume.

For the 11 water quality design volumes in the table, the Total Projected Unit Costs ranged from $224,468 to $782,627, as shown in Graph 8-3. The graph indicates that total unit cost decreases as design volume increases. For all 11 water quality design volumes, the Projected Required Site-Specific Unit Cost was the largest component of the total projected unit cost, with Projected Base BMP Unit Cost as the second largest component.

Graph 8-4 graphically represents the Total Projected Construction Cost data from Table 8-B in ascending order by water quality design volume. This graph shows the increase in the total projected cost of constructing an IB as the water quality design volume increases.

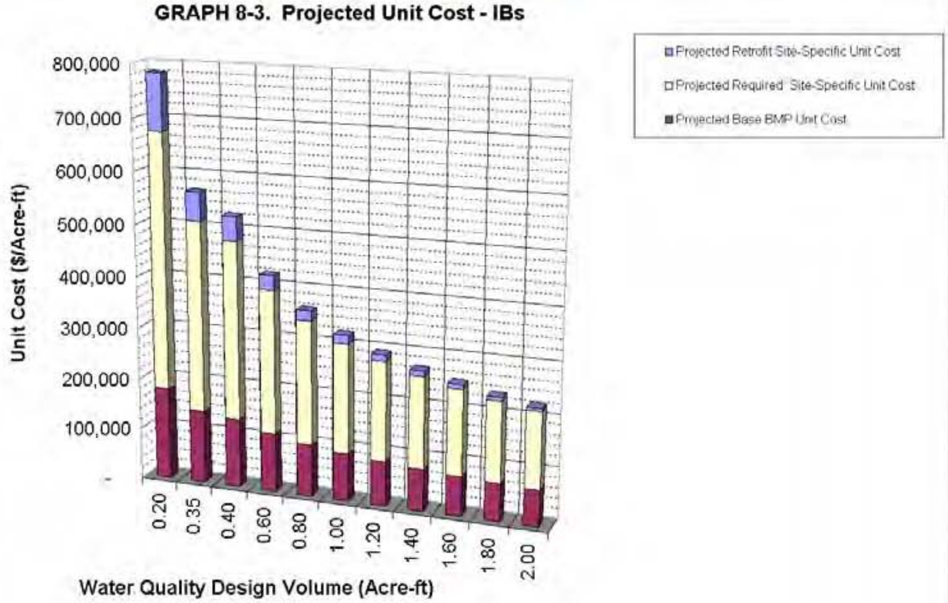
A maximum design discharge of 2.0 acre-ft was used for the analysis because the IBs constructed in the Pilot Program were relatively small (compared to those constructed by other agencies). One could reasonably expect the same unit cost savings trend to continue for greater water quality design volumes based on the retrofit construction process.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for IBs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an IB unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the IB is constructed using a process other than retrofit of an existing facility.

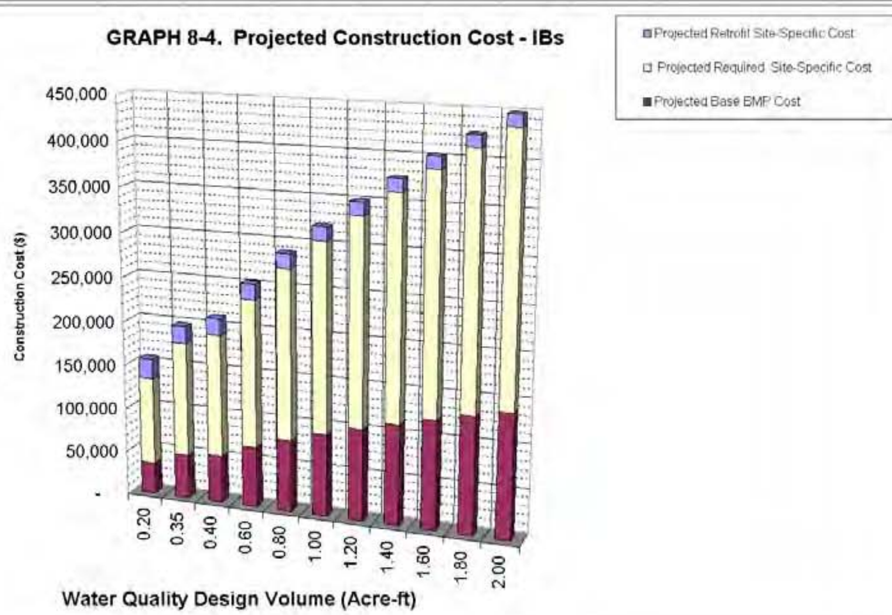
TABLE 8-B. PROJECTED CONSTRUCTION COSTS - IBs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Infiltration Basins												
111103	Typical Sites with Indicated Water Quality Volume	35,735	99,171	21,620	156,525			0.20	178,674	495,854	108,100	782,627
73101		49,865	129,238	19,224	198,327			0.35	142,471	369,250	54,925	566,647
		53,991	137,667	18,693	210,351			0.40	134,978	344,168	46,731	525,878
		68,734	166,785	17,167	252,686			0.60	114,556	277,975	28,612	421,144
		81,575	191,108	16,162	288,844			0.80	101,969	238,885	20,202	361,055
		93,166	212,391	15,422	320,979			1.00	93,166	212,391	15,422	320,979
		103,849	231,529	14,843	350,220			1.20	86,541	192,941	12,369	291,850
		113,831	249,048	14,370	377,250			1.40	81,308	177,892	10,265	269,464
		123,251	265,293	13,973	402,517			1.60	77,032	165,808	8,733	251,573
		132,205	280,499	13,632	426,335			1.80	73,447	155,833	7,573	236,853
		140,764	294,838	13,334	448,936			2.00	70,382	147,419	6,667	224,468

GRAPH 8-3. Projected Unit Cost - IBs



GRAPH 8-4. Projected Construction Cost - IBs



9. Infiltration Trench/Strip – Projected Construction Cost Analysis

This section projects construction costs for the Infiltration Trench/Strip (IT/STRP) BMP type. Adjusted cost data for the IT/STRP device is shown in Table 9-A, listed in ascending order by water quality design size. Water quality design units for the IT/STRP are specified by discharge in cfs.

Only two IT/STRPs were constructed as part of the Pilot Program. For this reason, the data for the two installations, and data derived from the BSTRP analysis, were used to generate sufficient data to project construction costs for the IT/STRP. Since the IT/STRP and BSTRP are similar in function, it is assumed that construction of the two devices is likewise similar.

The Base BMP Cost data for the IT/STRP in Table 9-A were generated as follows:

- The Base BMP Cost for the two Pilot Program installations is included. In Table 9-A, these are identified by WQ ID number.
- The BSTRP Base BMP Cost Curve (Graph 7-2) was adjusted to pass through the average of the two IT/STRP Base BMP Unit Costs for the two Pilot Program installations. This resulted in a BSTRP Curve Adjustment Factor of 3.05 (shown at the bottom of Table 9-A). This factor was then applied to the costs derived from the BSTRP Base BMP Cost Curve for each discharge. The resulting Base BMP Costs are identified in Table 9-A by their discharge sizes in the WQ ID No. column.
- The average of the Base BMP Cost for the two IT/STRPs constructed for the Pilot Program was calculated. In Table 8-A, this is identified as "Avg IT/STRP" in the WQ ID No. column.

The Required Site-Specific Cost data for the IT/STRP in Table 9-A were generated as follows:

- The known values for the two Pilot Program installations are included.
- The cost curve equation for the BSTRP Required Site-Specific Costs (Graph 7-2) is used to derive the values for the other IT/STRP water quality design discharges, including the Avg IT/STRP. It is assumed that the required site-specific costs would be the similar for the IT/STRP and BSTRP and, therefore, the adjustment factor is 1.00 (no adjustment).

The Retrofit Site-Specific Cost data for the IT/STRP in Table 9-A were generated as follows:

- The known values for the two Pilot Program installations are included.
- The cost curve equation for the BSTRP Retrofit Site-Specific Costs (Graph 7-2) is used to derive the values for the other IT/STRP water quality design discharges, including the Avg IT/STRP. It is assumed that the retrofit site-specific costs would be the similar for the IT/STRP and BSTRP and, therefore, the adjustment factor is 1.00 (no adjustment).

For the data in Table 9-A, the Total Adjusted Unit Costs ranged from $70,089 to $778,848 per cfs, as shown in Graph 9-1.

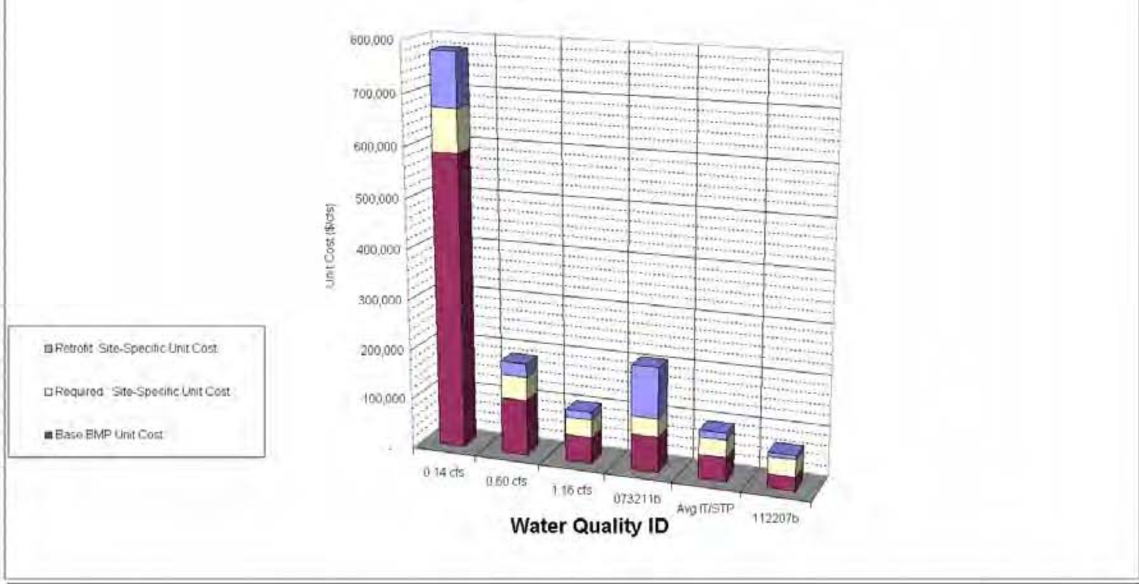
For all but one IT/STRP, the Base BMP Unit Cost was the largest component of the total adjusted unit cost. For four design discharges, the Required Site-Specific Unit Cost was the second most costly category. For two IT/STRPs, the Retrofit Site-Specific Cost tended to be the second most costly category.

The cost curves for each category, are shown in Graph 9-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design discharge increases.

TABLE 9-A. ADJUSTED UNIT COST - IT/STRP

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Infiltration Trench/Bio-Strip													
0.14 cfs	BSTRP		82,029	12,016	14,994	109,039	0.47	0.14	-	585,923	85,826	107,099	778,848
0.60 cfs	BSTRP		66,705	28,368	16,595	111,668	2.40	0.60	-	111,175	47,280	27,658	186,113
1.16 cfs	BSTRP		60,740	41,864	17,375	119,978	1.66	1.16	-	52,362	36,089	14,978	103,430
073211b	IT/STRP	Altadena Maint. Station	82,346	42,537	116,717	241,601	1.66	1.16	0.14	70,988	36,670	100,618	208,277
Avg IT/STP		Average	59,973	44,133	17,483	121,589		1.27	-	47,279	34,791	13,783	95,853
112207b	IT/STRP	Carlsbad Maint. Station (east)	37,599	47,277	11,637	96,512	2.40	1.38	0.18	27,305	34,333	8,451	70,069
	BSTRP Curve Adjustment Factor		3.05	1.00	1.00								
	Average IT/STRP		$59,973	$44,907	$64,177			1.27					

GRAPH 9-1. Adjusted Unit Cost - IT/STRPs



GRAPH 9-2. Adjusted Unit Cost Curves - IT/STRPs

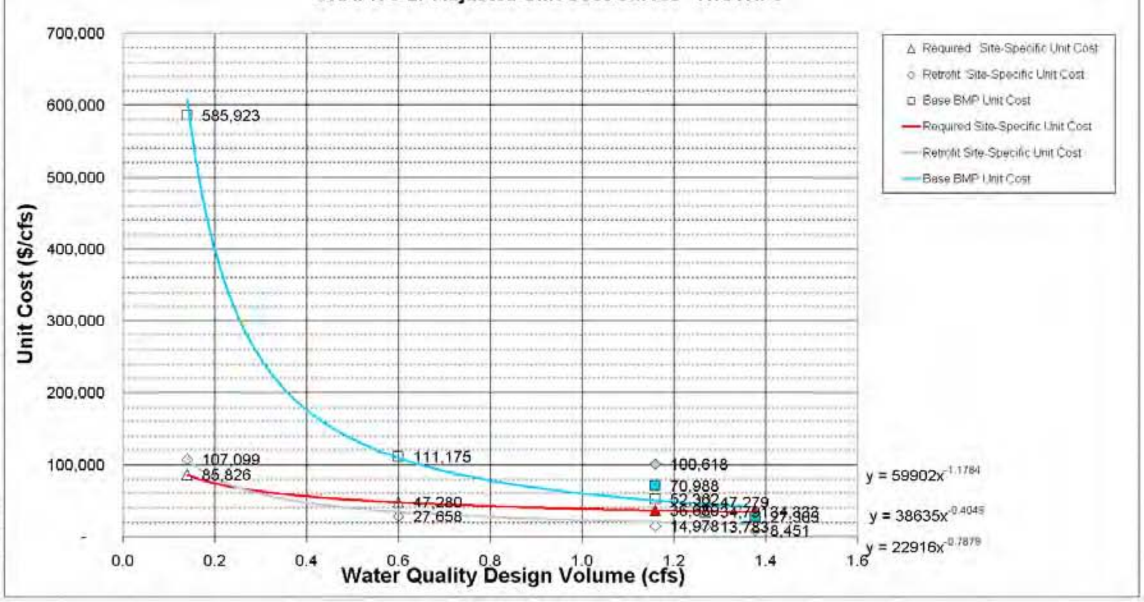


Table 9-B shows projected cost data derived using the cost curve equations from Graph 9-2 for 10 different water quality design discharges; the two associated with the Pilot Program installations, and eight additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the 10 water quality design discharges in the table, the Total Projected Unit Costs ranged from $28,565 to $226,292, as shown in Graph 9-3. The graph indicates that total unit cost decreases as design discharge increases. For the four largest design discharges, the Projected Base BMP Unit Cost was the largest component of the total projected cost. For the six smallest design discharges, the Projected Required Site-Specific Unit Costs were the most costly category.

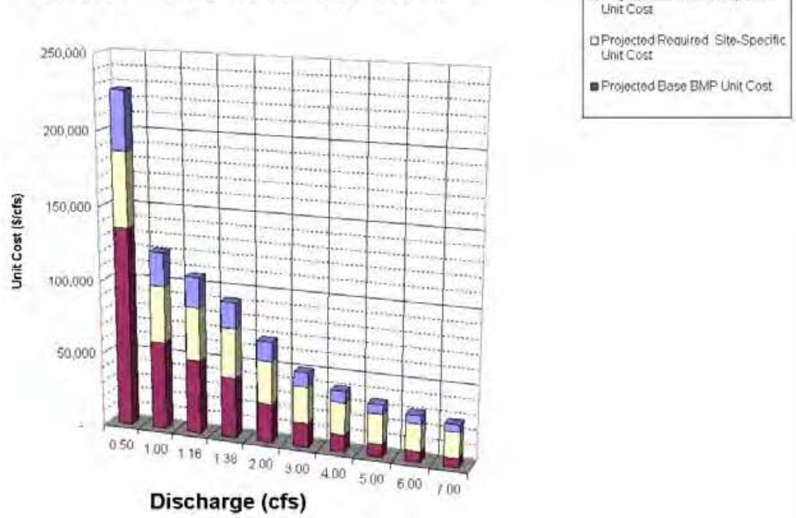
Graph 9-4 graphically represents the Total Projected Construction Cost data from Table 9-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing an IT/STRP as the water quality design discharge increases.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for IT/STRPs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an IT/STRP unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the IT/STRP is constructed using a process other than retrofit of an existing facility.

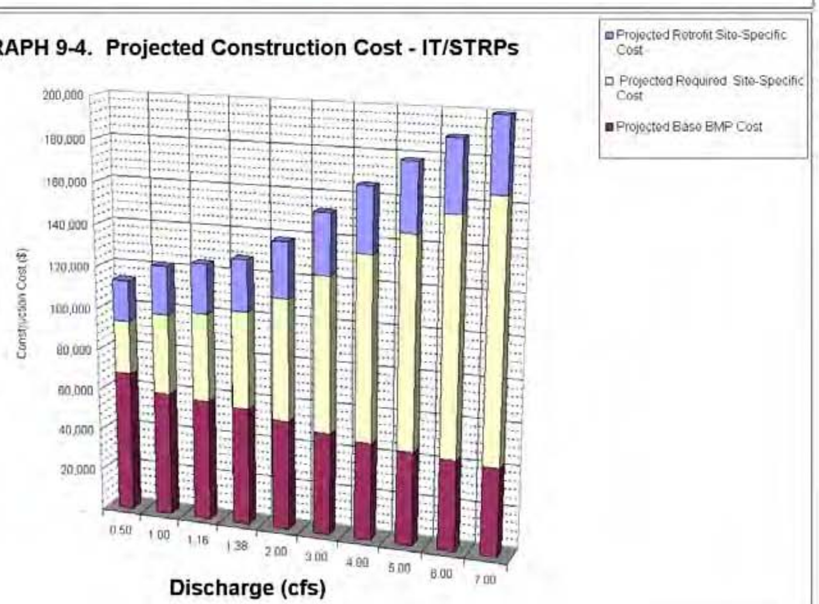
TABLE 9-B. PROJECTED CONSTRUCTION COSTS - IT/STRPs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/cfs)	Projected Required Site-Specific Unit Cost ($/cfs)	Projected Retrofit Site-Specific Unit Cost ($/cfs)	Total Projected Unit Cost ($/cfs)
Infiltration Trench/Strip												
	Typical Site with Indicated Discharge	67,787	25,576	19,783	113,146		0.50		135,574	51,153	39,566	226,292
		59,902	38,635	22,916	121,453		1.00		59,902	38,635	22,916	121,453
073211b		58,337	42,203	23,649	124,188	1.66	1.16	0.14	50,290	36,382	20,387	107,059
112207b		56,579	46,737	24,525	127,841	2.40	1.38	0.18	41,089	33,941	17,810	92,840
		52,934	58,361	26,545	137,841		2.00		26,467	29,181	13,273	68,920
		49,241	74,288	28,929	152,457		3.00		16,414	24,763	9,643	50,819
		46,777	88,159	30,749	165,686		4.00		11,694	22,040	7,687	41,421
		44,952	100,679	32,240	177,870		5.00		8,990	20,136	6,448	35,574
		43,513	112,217	33,511	189,241		6.00		7,252	18,703	5,585	31,540
		42,333	122,998	34,625	199,955		7.00		6,048	17,571	4,946	28,565

GRAPH 9-3. Projected Unit Cost - IT/STRPs



GRAPH 9-4. Projected Construction Cost - IT/STRPs



10. Wet Basin – Projected Construction Cost Analysis

This section projects construction costs for the Wet Basin (WB) BMP type. Adjusted cost data for the WB device is shown in Table 8-A, listed in ascending order by water quality design size. Water quality design units for the WB are specified as volume in acre-ft.

Only one WB was constructed as part of the Pilot Program. For this reason, the data for the one installation, and data derived from the EDB analysis, were used to generate sufficient data to project construction costs for the WB.

The Base BMP Cost data for the WB in Table 10-A were generated as follows:

- The Base BMP Cost for the one Pilot Program installation is included. In Table 10-A, this is identified by WQ ID number.
- The EBD Base BMP Cost Curve (Graph 1-2) was adjusted to pass through the WB Base BMP Unit Cost for the Pilot Program installation. This resulted in an EDB Curve Adjustment Factor of 4.98 (shown at the bottom of Table 10-A). This factor was then applied to the costs derived from the EDB Base BMP Cost Curve for each volume. The resulting Base BMP Costs are identified in Table 10-A by their volumes in the WQ ID No. column.
- The average of the Base BMP Cost for the WB constructed for the Pilot Program was calculated. Since there was only one installation for the BMP type, the average Base BMP Cost is the same as the Base BMP Cost for the one installed BMP. In Table 10-A, this is identified as “Avg WB” in the WQ ID No. column.

The Required Site-Specific Cost data for the WB in Table 10-A were generated as follows:

- The known value for the one Pilot Program installation is included.
- The cost curve equation for the EDB Required Site-Specific Costs (Graph 1-2) is used to derive the values for the other WB water quality design volumes, including the Avg WB. It is assumed that the required site-specific costs would be the similar for the WB and EDB and, therefore, the adjustment factor is 1.00 (no adjustment).

The Retrofit Site-Specific Cost data for the WB in Table 10-A were generated as follows:

- The known value for the one Pilot Program installation is included.
- The cost curve equation for the EBD Retrofit Site-Specific Costs (Graph 1-2) is used to derive the values for the other WB water quality design volumes, including the Avg WB. It is assumed that the retrofit site-specific costs would be the similar for the WB and EDB and, therefore, the adjustment factor is 1.00 (no adjustment).

For the data in Table 10-A, the Total Adjusted Unit Costs ranged from $842,517 to $2,612,855 per acre-ft, as shown in Graph 10-1.

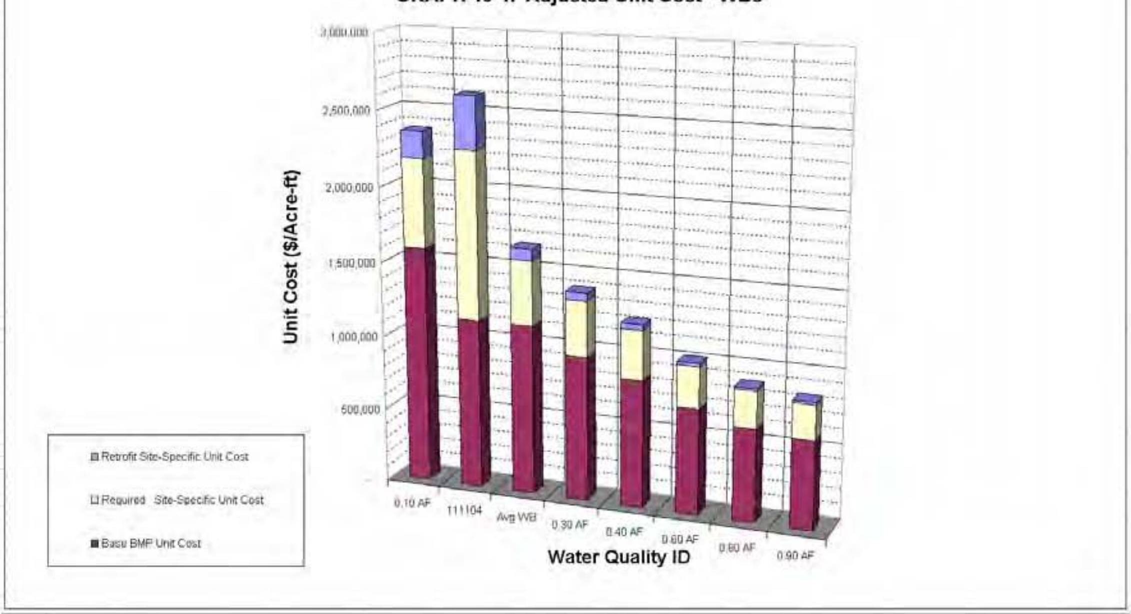
For all WBs, the Base BMP Unit Cost was the largest component of the total adjusted unit cost, with the Required Site-Specific Unit Cost as the second most costly category.

The cost curves for each category, are shown in Graph 10-2. Based on the trends shown by the cost curves, the unit costs in each category are projected to decrease as water quality design volume increases.

TABLE 10-A. ADJUSTED UNIT COSTS - WBs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/Acre-ft)	Required Site-Specific Unit Cost ($/Acre-ft)	Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Adjusted Unit Cost ($/Acre-ft)
Wet Basins													
0.10 AF			158,940	59,538	17,812	236,290			0.10	1,589,400	595,379	178,117	2,362,897
111104	WB	I-5/La Costa (east)	239,297	235,730	73,673	548,700	4.20	2.23	0.21	1,139,510	1,122,522	350,824	2,612,855
Avg WB			239,297	91,297	16,077	346,671			0.21	1,139,510	434,748	76,557	1,650,815
0.30 AF			291,317	112,127	15,304	418,748			0.30	971,056	373,757	51,014	1,395,828
0.40 AF			339,990	131,770	14,724	486,484			0.40	856,398	331,915	37,087	1,225,400
0.60 AF			426,957	167,172	13,907	608,036			0.60	711,594	278,621	23,179	1,013,394
0.80 AF			500,366	197,312	13,366	711,044			0.80	625,457	246,640	16,707	888,804
0.90 AF			533,947	211,168	13,150	758,265			0.90	593,274	234,631	14,611	842,517
	EDB Curve Adjustment Factor		4.98	1.00	1.00								
	Average WB		$ 239,297	$ 235,730	$ 73,673				0.21				

GRAPH 10-1. Adjusted Unit Cost - WBs



GRAPH 10-2. Adjusted Unit Cost Curves - WBs

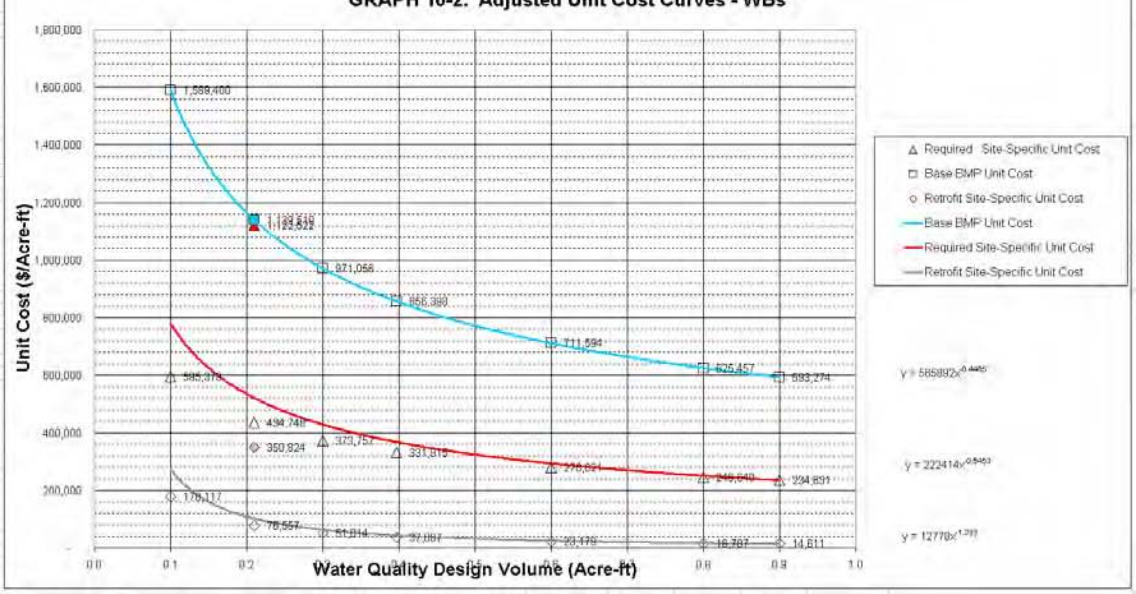


Table 10-B shows projected cost data derived using the cost curve equations from Graph 10-2 for 10 different water quality design volumes; the one associated with the Pilot Program installation, and nine additional volumes representing a typical range of values. The data are listed in ascending order by water quality design volume.

For the 10 water quality design discharges in the table, the Total Projected Unit Costs ranged from $572,169 to $1,762,728, as shown in Graph 10-3. The graph indicates that total unit cost decreases as design volume increases. For all 11 water quality design volumes, the Projected Base BMP Unit Cost was the largest component of the total projected unit cost, with Required Site-Specific Unit Cost as the second largest component.

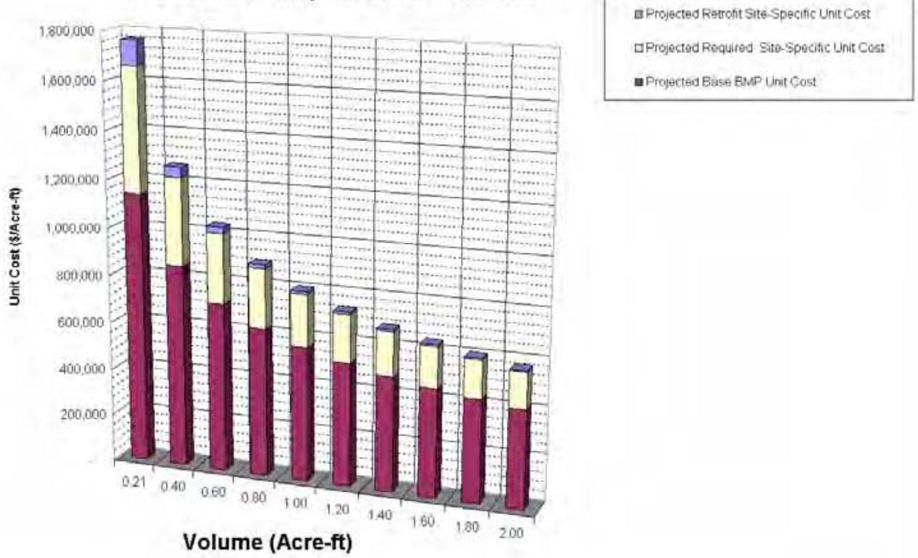
Graph 10-4 graphically represents the Total Projected Construction Cost data from Table 10-B in ascending order by water quality design volume. This graph shows the increase in the total projected cost of constructing a WB as the water quality design volume increases. The graph also shows that Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design volume.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for WBs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of a WB unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the WB is constructed using a process other than retrofit of an existing facility.

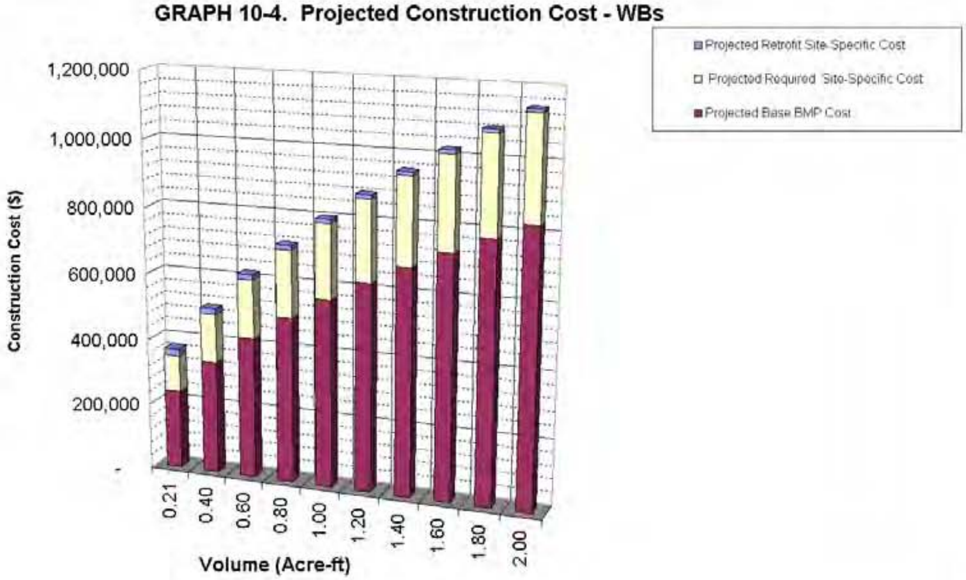
TABLE 10-B. PROJECTED CONSTRUCTION COSTS - WBs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/Acre-ft)	Projected Required Site-Specific Unit Cost ($/Acre-ft)	Projected Retrofit Site-Specific Unit Cost ($/Acre-ft)	Total Projected Unit Cost ($/Acre-ft)
Wet Basin												
111104		239,297	109,389	21,486	370,173	4.20	2.23	0.21	1,139,510	520,902	102,316	1,762,728
	Typical Sites with Indicated Water Quality Volume	341,405	146,629	17,337	505,371			0.40	853,512	366,572	43,343	1,263,426
		426,957	176,314	15,147	618,419			0.60	711,595	293,857	25,246	1,030,698
		500,366	200,954	13,764	715,084			0.80	625,457	251,193	17,205	893,855
		565,892	222,414	12,778	801,084			1.00	565,892	222,414	12,778	801,084
		625,752	241,638	12,025	879,415			1.20	521,460	201,365	10,021	732,846
		681,276	259,183	11,424	951,883			1.40	486,626	185,131	8,160	679,916
		733,341	275,407	10,927	1,019,675			1.60	458,338	172,130	6,829	637,297
		782,558	290,559	10,506	1,083,623			1.80	434,754	161,422	5,837	602,013
		829,376	304,818	10,144	1,144,338			2.00	414,688	152,409	5,072	572,169

GRAPH 10-3. Projected Unit Cost - WBs



GRAPH 10-4. Projected Construction Cost - WBs



11. Drain Inlet Insert – Projected Construction Cost Analysis

This section projects construction costs for the Drain Inlet Insert (DII) BMP type. Table 11-A presents the adjusted unit costs for six DII devices constructed as part of the Caltrans Pilot Program, listed in ascending order by water quality design size. Water quality design units for the DII are specified by discharge in cfs.

For the six DII installations analyzed from the Pilot Program, the Total Adjusted Unit Costs ranged from $755 to 9,486 per cfs, as shown in Graph 11-1.

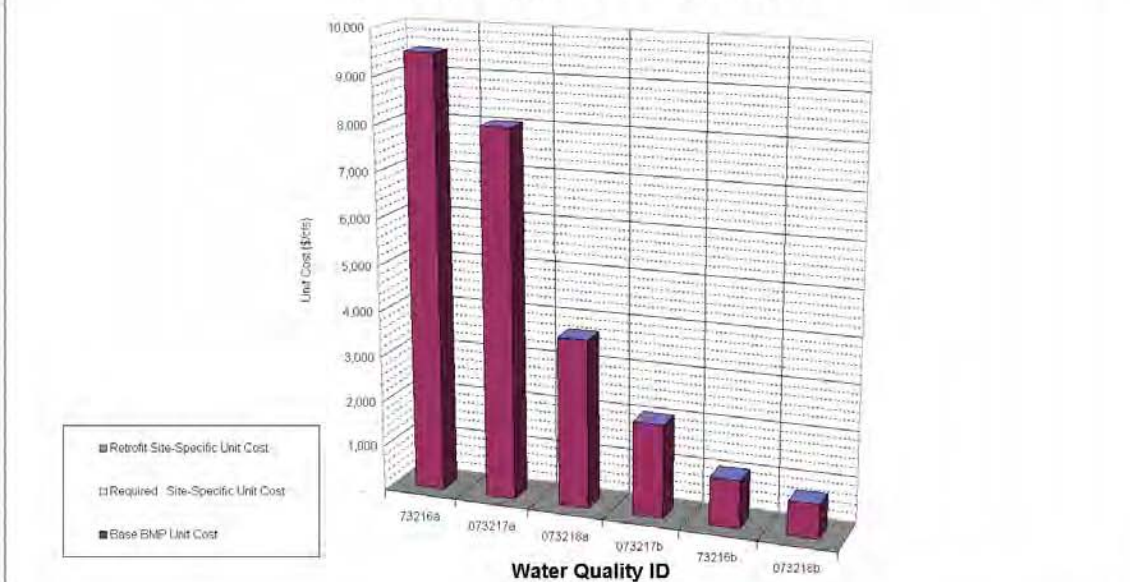
For all installations, Base BMP Unit Cost was the only category with costs allocated to it.

The cost curve for Base BMP Unit Cost is shown in Graph 11-2. Based on the trends shown by the cost curve, the Base BMP Unit Cost is projected to decrease as water quality design discharge increases.

TABLE 11-A. ADJUSTED UNIT COSTS - DIIs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/cfs)	Required Site-Specific Unit Cost ($/cfs)	Retrofit Site-Specific Unit Cost ($/cfs)	Total Adjusted Unit Cost ($/cfs)
Drain Inlet Inserts													
73216a	DII	Foothill Maint. Station	370	-	-	370	0.17	0.04	-	9,486	-	-	9,486
073217a	DII	Las Flores Maint. Station	370	-	-	370	0.23	0.05	-	8,042	-	-	8,042
073218a	DII	Rosemead Maint. Station	370	-	-	370	0.25	0.10	-	3,700	-	-	3,700
073217b	DII	Las Flores Maint. Station	370	-	-	370	0.78	0.18	-	2,055	-	-	2,055
73216b	DII	Foothill Maint. Station	370	-	-	370	1.58	0.35	-	1,057	-	-	1,057
073218b	DII	Rosemead Maint. Station	370	-	-	370	1.20	0.49	-	755	-	-	755

GRAPH 11-1. Adjusted Unit Cost By Site - DIIs



GRAPH 11-2. Adjusted Unit Cost Curve - DIIs

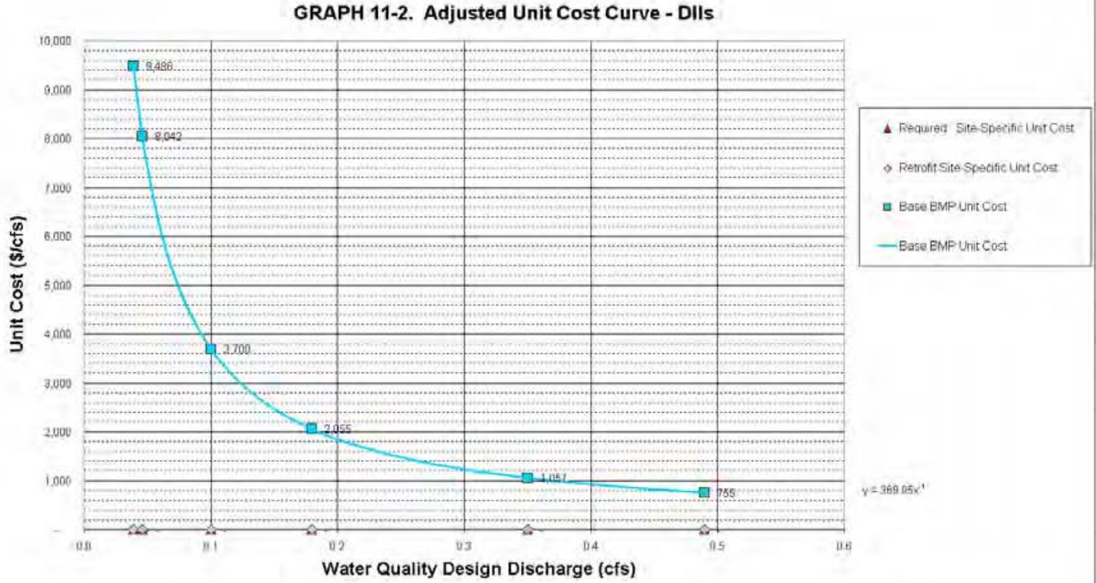


Table 11-B shows projected cost data derived using the cost curve equation from Graph 11-2 for nine different water quality design discharges; the six associated with the Pilot Program installations, and three additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

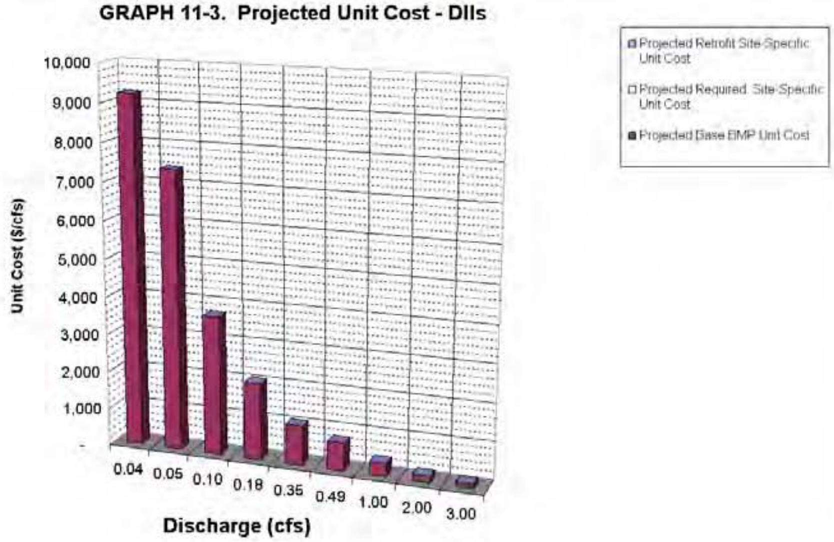
For the nine water quality design discharges in the table, the Total Projected Unit Costs ranged from $123 to $9,249, as shown in Graph 11-3. The graph shows that total unit cost decreases as design discharge increases.

Graph 11-4 graphically represents the Total Projected Construction Cost data from Table 11-B in ascending order by water quality design discharge. This graph shows a constant projected construction cost for all design discharges included in the graph.

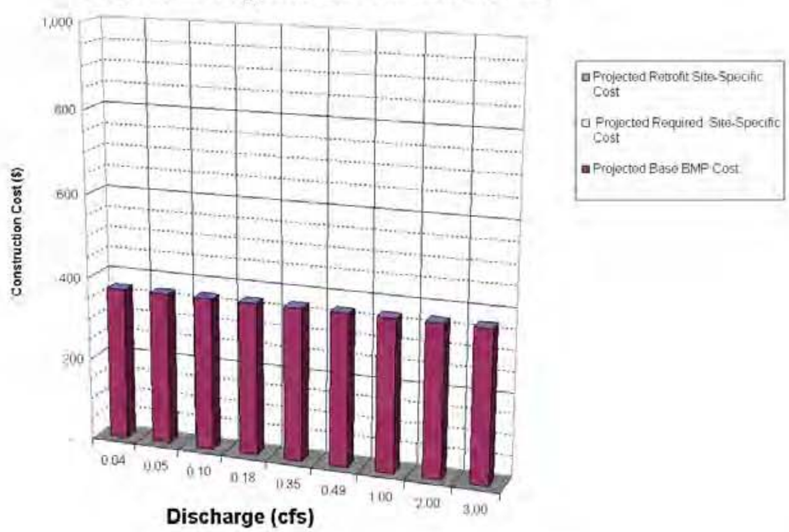
TABLE 11-B. PROJECTED CONSTRUCTION COSTS - DIIs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/cfs)	Projected Required Site-Specific Unit Cost ($/cfs)	Projected Retrofit Site-Specific Unit Cost ($/cfs)	Total Projected Unit Cost ($/cfs)
Drain Inlet Inserts												
073216a	Typical Site with Indicated Discharge	370	-	-	370	0.17	0.04	-	9,249	-	-	9,249
073217a		370	-	-	370	0.23	0.05	-	7,399	-	-	7,399
073218a		370	-	-	370	0.25	0.10	-	3,700	-	-	3,700
073217b		370	-	-	370	0.78	0.18	-	2,055	-	-	2,055
073216b		370	-	-	370	1.58	0.35	-	1,057	-	-	1,057
073218b		370	-	-	370	1.20	0.49	-	755	-	-	755
		370	-	-	370		1.00		370	-	-	370
		370	-	-	370		2.00		185	-	-	185
		370	-	-	370		3.00		123	-	-	123

GRAPH 11-3. Projected Unit Cost - DIIs



GRAPH 11-4. Projected Construction Cost - DIIs



12. Oil/Water Separator – Projected Construction Cost Analysis

This section projects construction costs for the Oil/Water Separator (OWS) BMP type. Adjusted cost data for the OWS device is shown in Table 12-A, listed in ascending order by water quality design size. Water quality design units for the OWS are specified by discharge in cfs.

Only one OWS was constructed as part of the Pilot Program. For this reason, the data for the OWS was combined with the data for the Continuous Deflection Separator (CDS) to provide additional data to project construction costs for both devices.

For the data in Table 12-A, the Total Adjusted Unit Costs ranged from $95,016 to $192,610 per cfs, as shown in Graph 12-1.

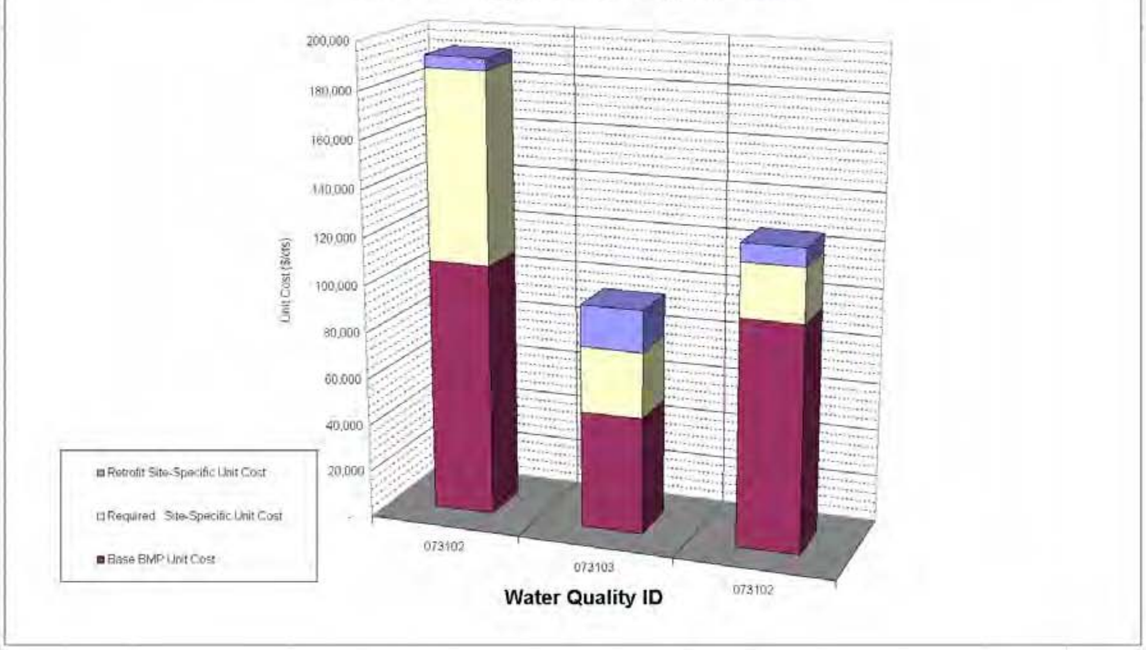
For all three installations, the Base BMP Unit Cost was the largest component of the total adjusted unit cost, followed by the Required Site-Specific Unit Cost.

The cost curves for each cost category, are shown in Graph 12-2. Based on the trends shown by the cost curves, the unit costs for the Base BMP Unit Cost and the Required Site-Specific Unit Cost are projected to decrease as water quality design discharge increases, while the Retrofit Site-Specific Unit Cost would increase with design discharge.

TABLE 12-A. ADJUSTED UNIT COSTS - OWSs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/cfs)	Required Site-Specific Unit Cost ($/cfs)	Retrofit Site-Specific Unit Cost ($/cfs)	Total Adjusted Unit Cost ($/cfs)
Oil Water Separators													
073102	CDS	I-210/Orcas Ave	26,843	20,052	1,258	48,153	1.09	0.25	-	107,372	80,208	5,030	192,610
073103	CDS	I-210/Fillmore Ave	28,699	16,160	10,250	55,109	1.74	0.58	-	49,481	27,862	17,672	95,016
073102	OWS	Alameda Maint. Station	101,534	24,158	8,216	133,908	0.75	1.06	0.05	95,786	22,791	7,751	126,329

GRAPH 12-1. Adjusted Unit Cost By Site - OWSs



GRAPH 12-2. Adjusted Unit Cost Curves - OWSs

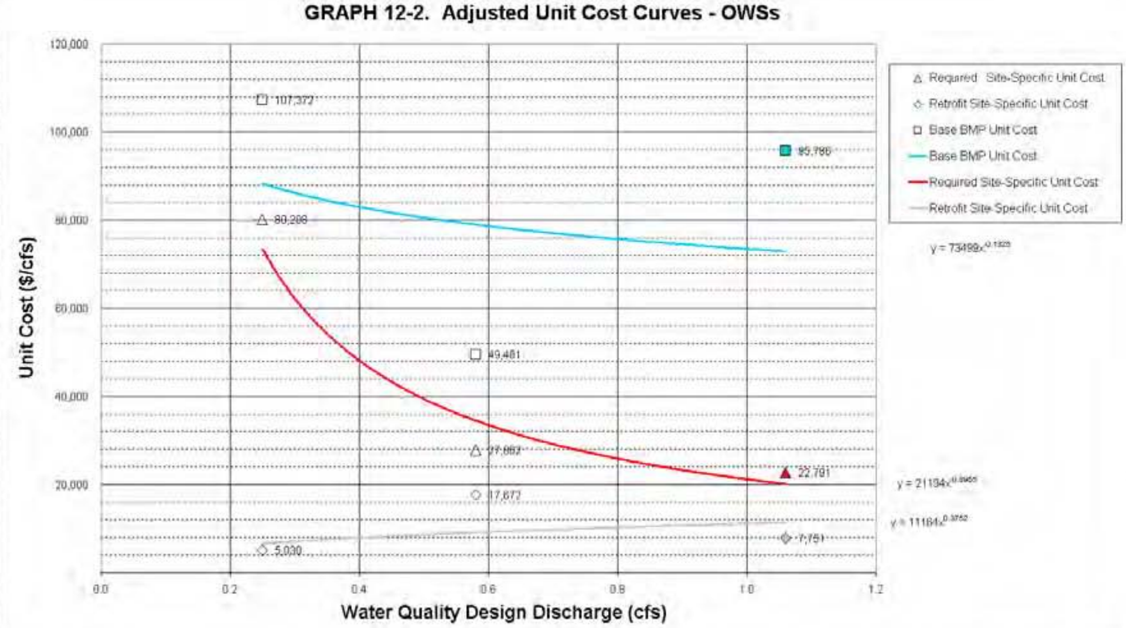


Table 12-B shows projected cost data derived using the cost curve equations from Graph 12-2 for six different OWS water quality design discharges; the three devices associated with the Pilot Program installation shown in Table 12-A, and three additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

For the six water quality design discharges in the table, the Total Projected Unit Costs ranged from $41,927 to $541,308, as shown in Graph 12-3. The graph indicates that total unit cost decreases as design volume increases. The Projected Base BMP Unit Cost was the largest component of the total projected cost for all design discharges.

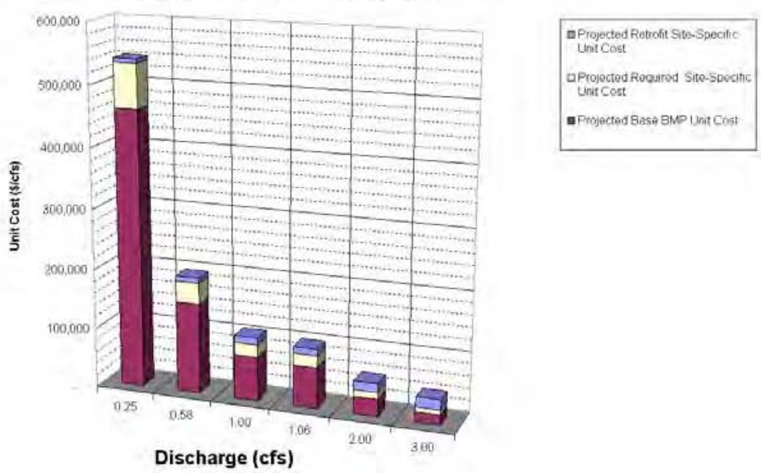
Graph 12-4 graphically represents the Total Projected Construction Cost data from Table 12-B in ascending order by water quality design discharge. This graph shows no clear trend in projecting construction cost using design discharge as a predictive factor. This is likely due to the lack of data available for the analysis.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for OWSs is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of an OWS unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the OWS is constructed using a process other than retrofit of an existing facility.

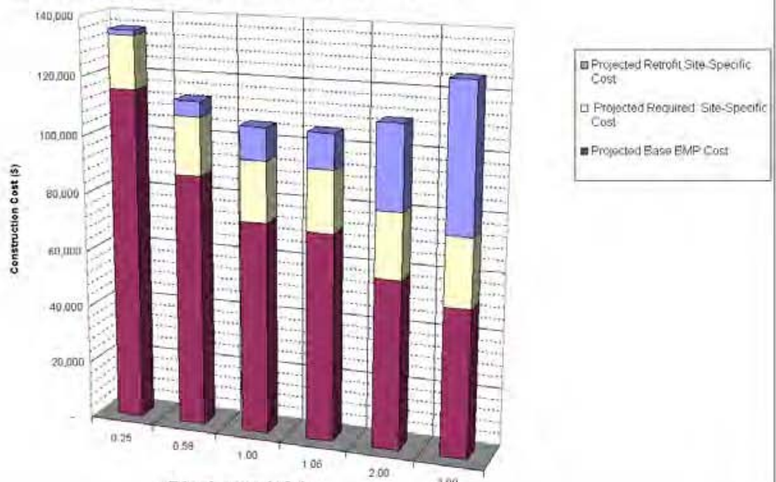
TABLE 12-B. PROJECTED CONSTRUCTION COSTS - OWSs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/cfs)	Projected Required Site-Specific Unit Cost ($/cfs)	Projected Retrofit Site-Specific Unit Cost ($/cfs)	Total Projected Unit Cost ($/cfs)
Oil Water Separator												
	Typical Site with Indicated Discharge	115,332	18,336	1,659	135,327		0.25		461,329	73,343	6,636	$541,308
		87,734	20,021	5,278	113,033		0.58		151,265	34,519	9,100	$194,885
		73,499	21,194	11,164	105,857		1.00		73,499	21,194	11,164	$105,857
074201		72,120	21,323	12,095	105,539	0.75	1.06	-	68,038	20,116	11,411	$99,565
		58,674	22,786	28,960	110,420		2.00		29,337	11,393	14,480	$55,210
		51,430	23,772	50,577	125,780		3.00		17,143	7,924	16,859	$41,927

GRAPH 12-3. Projected Unit Cost - OWSs



GRAPH 12-4. Projected Construction Cost - OWSs



13. Continuous Deflection Separator – Projected Construction Cost Analysis

This section projects construction costs for the Continuous Deflection Separator (CDS) BMP type. Adjusted cost data for the CDS device is shown in Table 13-A, listed in ascending order by water quality design size. Water quality design units for the CDS are specified by discharge in cfs.

Only two CDS devices were constructed as part of the Pilot Program. For this reason, the data for the CDS was combined with the data for the OWS to provide additional data to project construction costs for both devices.

For the data in Table 13-A, the Total Adjusted Unit Costs ranged from \$95,016 to \$192,610 per cfs, as shown in Graph 13-1.

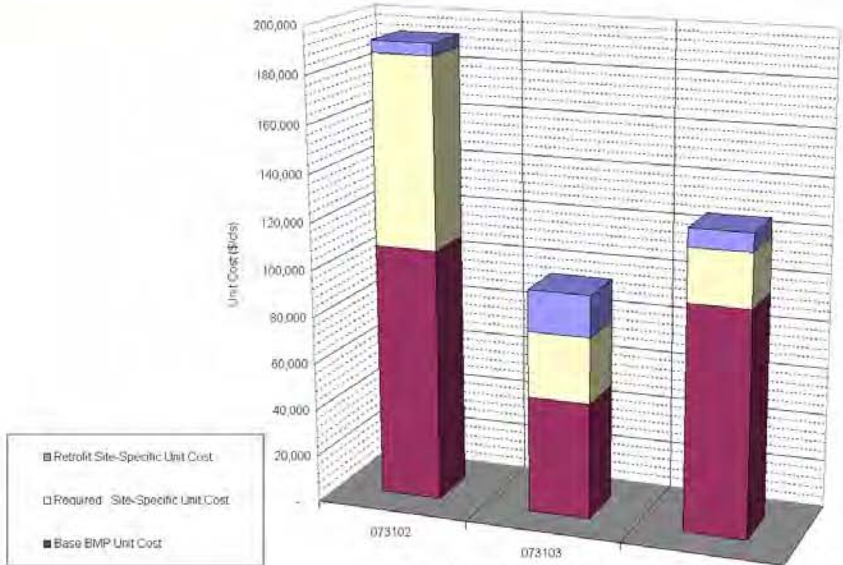
For all three installations, the Base BMP Unit Cost was the largest component of the total adjusted unit cost, followed by the Required Site-Specific Unit.

The cost curves for each cost category, are shown in Graph 13-2. Based on the trends shown by the cost curves, the unit costs for the Base BMP Unit Cost and the Required Site-Specific Unit Cost are projected to decrease as water quality design discharge increases, while the Retrofit Site-Specific Unit Cost would increase with design discharge.

TABLE 13-A. ADJUSTED UNIT COSTS - CDSs

WQ ID No.	BMP Type	Site Location	Base BMP Cost ($)	Required Site-Specific Cost ($)	Retrofit Site-Specific Cost ($)	Total Adjusted Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Base BMP Unit Cost ($/cfs)	Required Site-Specific Unit Cost ($/cfs)	Retrofit Site-Specific Unit Cost ($/cfs)	Total Adjusted Unit Cost ($/cfs)
Continuous Deflection Separators													
073102	CDS	I-210/Orcas Ave	26,843	20,052	1,258	48,153	1.09	0.25	-	107,372	80,208	5,030	192,610
073103	CDS	I-210/Fillmore Ave	28,699	16,160	10,250	55,109	1.74	0.58	-	49,481	27,862	17,672	95,016
074201	OWS	Alameda Maint. Station	101,534	24,158	8,216	133,908	0.75	1.06	0.05	95,786	22,791	7,751	126,329

GRAPH 13-1. Adjusted Unit Cost By Site - CDSs



GRAPH 13-2. Adjusted Unit Cost Curves - CDSs

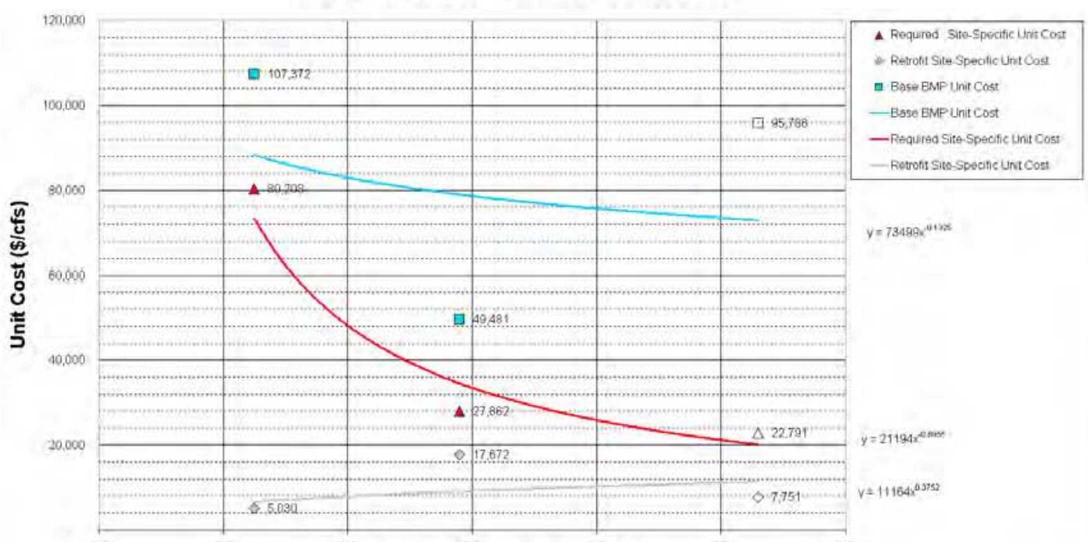


Table 13-B shows projected cost data derived using the cost curve equations from Graph 13-2 for five different CDS water quality design discharges; the two associated with the Pilot Program installations, and three additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

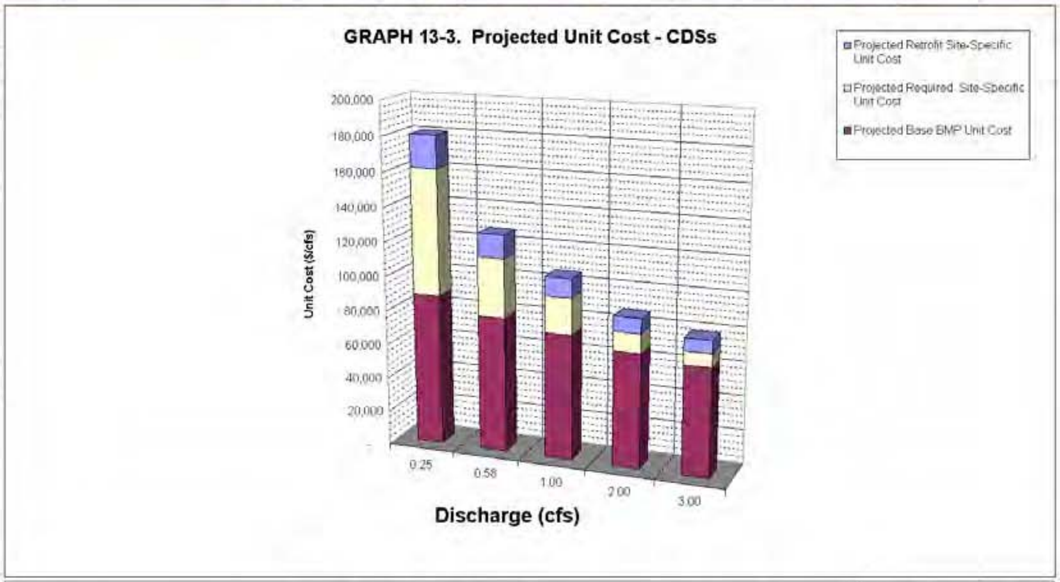
For the five water quality design discharges in the table, the Total Projected Unit Costs ranged from $78,859 to $180,443, as shown in Graph 13-3. The graph indicates that total unit cost decreases as design volume increases. The Projected Base BMP Unit Cost was the largest component of the total projected cost for all design discharges, with Projected Required Site-Specific Unit Cost the second most costly category.

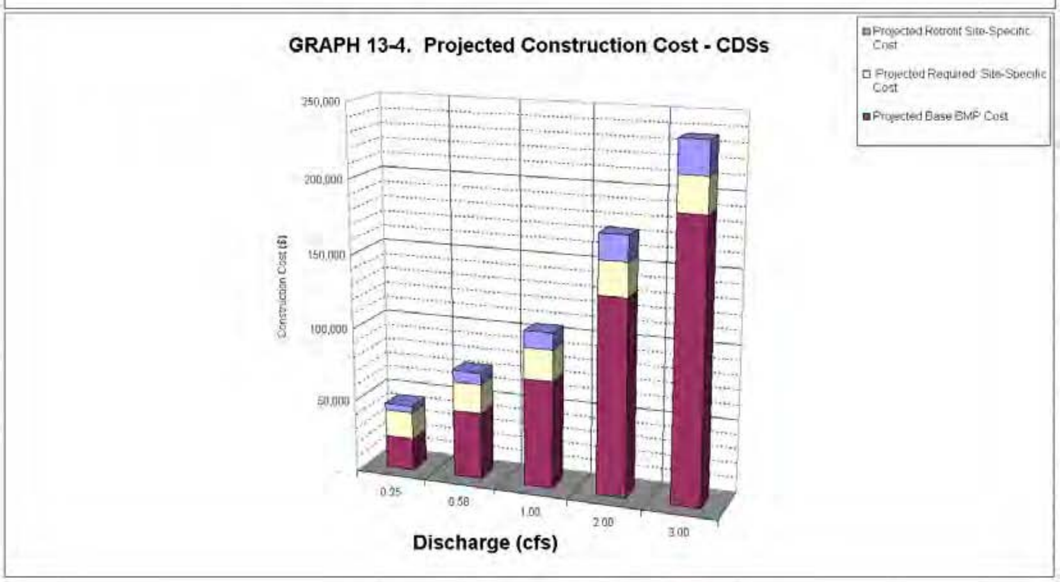
Graph 13-4 graphically represents the Total Projected Construction Cost data from Table 13-B in ascending order by water quality design discharge. This graph shows the increase in the total projected cost of constructing a CDS as the water quality design discharge increases. The graph also shows that costs for Projected Base BMP Cost accounts for the greatest portion of the total cost regardless of design discharge.

Although difficult to ascertain, it is likely that the primary factor for a reduction in unit cost for CDS device is construction efficiency (economy of scale). This cost reduction factor cannot be applied to the construction cost of a CDS unless constructed as a part of major redevelopment or new construction, and not as a retrofit to an existing facility. Likewise, the Retrofit Site-Specific Costs can be eliminated from the total projected construction cost, if the CDS is constructed using a process other than retrofit of an existing facility.

TABLE 13-B. PROJECTED CONSTRUCTION COSTS - CDSs

WQ ID No.	Site Location	Projected Base BMP Cost ($)	Projected Required Site-Specific Cost ($)	Projected Retrofit Site-Specific Cost ($)	Total Projected Construction Cost ($)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Base BMP Unit Cost ($/cfs)	Projected Required Site-Specific Unit Cost ($/cfs)	Projected Retrofit Site-Specific Unit Cost ($/cfs)	Total Projected Unit Cost ($/cfs)
Continuous Deflection Separators												
073102	Typical Site with Indicated Discharge	22,080	18,336	4,695	45,111	1.09	0.25		88,319	73,343	18,781	180,443
073103		45,820	20,021	7,943	73,785	1.74	0.58		79,000	34,519	13,696	127,215
		73,499	21,194	11,164	105,857		1.00		73,499	21,194	11,164	105,857
		134,099	22,786	17,215	174,100		2.00		67,049	11,393	8,607	87,050
		190,627	23,772	22,178	236,577		3.00		63,542	7,924	7,393	78,859





E. Projected Operations and Maintenance Costs

The purpose of this section is to project the estimated O&M costs of the various BMP installations of the Pilot Program based on the information provided by the *BMP Retrofit Pilot Project Quarterly Status Report No. 10* prepared by RBF. These estimated costs projected for O&M for the particular BMP type are derived from the Pilot Program.

An OM&M plan was developed for the Pilot Program to provide guidance for operations, maintenance, and monitoring of BMP devices. The plan goal was to initiate procedures that resulted in consistent evaluation of the BMP devices in terms of the efficiency of constituent removal, assessment of design and construction, evaluation of operational capabilities, and tracking of OM&M costs.

Within the overall plan, a specific OM&M strategy was developed for each BMP device based on the document *Operation, Maintenance and Management of Storm Water Management Systems* (Watershed Management Institute and the United States Environmental Protection Agency, August 1997). Guidelines for obtaining and processing data were initiated giving personnel tasks to perform at scheduled time intervals, and guidelines for management of unscheduled events.

The five main areas of focus covered in the OM&M plan are as follows:

- Operation and Maintenance: This section sets standards and schedules for inspections and maintenance based on existing agency and government regulations.
- Vector Control Management: Generally confined to BMP devices that involve water retention, this section sets standards for water, and vegetation management. Abatement procedures are also defined for areas that may develop either rodent or mosquito problems.
- Health and Safety: Development of written procedures for safety, including workers at the BMP site, public safety and environmental safety.
- Monitoring, Sampling and Analysis Plan: Sets guidelines for water quality monitoring and data collection to determine BMP effectiveness in removing heavy metals and organic pollutants from runoff water.
- Program Documentation: Provides guidelines for documentation of the data collection and analysis process.

Costs related to OM&M were recorded by the consulting firms collecting data, and compiled in the Quarterly Status Reports prepared by RBF.

The following steps were followed to derive projected O&M costs for the 13 BMP types:

1. For each of the 39 BMP installations of the Pilot Program, the administrative, operation, vector control, equipment, and direct costs (O&M costs) were identified, and the aggregate of all costs, less administrative cost, were identified as the Total O&M Costs.

2. For each of the 39 BMP installations, an aggregate cost based on the water quality design unit was calculated.
3. The Annual O&M Unit Cost of each BMP installation by BMP type was plotted.
4. Unit cost curves for each BMP type were developed using a simple power trend-line with the form $y=cx^6$ drawn through the points for the Annual O&M Unit Cost.
5. Using the unit cost curve for a range of water quality design units, Projected Annual O&M Unit Costs and Projected Annual O&M Costs by water quality design unit were graphed.

Sections II.E.1 through II.E.13 contain the projected O&M costs for the 13 BMP types in the Pilot Program, presented in the same order as in Section II.D.

Each section contains the following tables and graphs to present the O&M unit cost and projected cost data for the BMP type.

- Annual O&M Unit Costs table (results of step 1 and 2 above)
- Annual O&M Unit Cost bar graph (results of step 3 above)
- Annual O&M Unit Cost Curve graph (results of step 4 above)
- Projected Annual O&M Costs table (tabular results of step 5 above)
- Projected Annual O&M Unit Cost bar graph (graphical results of step 5 above)
- Projected Annual O&M Cost bar graph (graphical results of step 5 above)

The formats of the tables and graphs are described below.

Annual O&M Unit Cost Table

The table of Annual O&M Unit Costs shows the derivation of the water quality design unit cost for each of the installations of that type of BMP in the Pilot Program. The table contains the following information listed in ascending order by water quality design size.

WQ ID No.: Unique Water Quality (WQ) Site Identification (ID) Number assigned to the 39 BMP installation in the Pilot Program. Refer to Section II.A for details.

BMP Type: BMP type using the abbreviations indicated in Section II.D.

Site Location: The physical location of the BMP device by road, highway, or maintenance station name. See Section II.A for details.

Administrative Cost: Administrative costs are comprised of general program support/follow-up, permits, travel, and unscheduled events. Administrative costs associated with support and follow-up consist of office support preparing and maintaining action plans, review of quality assurance data, weather tracking, management of collected data, records maintenance, ordering sampling equipment, and preparing reports. Permit costs were primarily for encroachment and related to access and safety issues during OM&M activities. Travel costs resulted from labor and equipment hours to and from BMP sites and meetings for the purpose of evaluations, data collection, and maintenance. Costs for unscheduled events include office time required to support pumping activities, equipment breakdowns, power outages, or storm events.

Operation Cost: Operations costs related to OM&M indicate labor and equipment hours used for inspections and field calls that were accomplished within a given time interval. Scheduled inspections include wet season inspections and dry season inspections. Costs were also incurred for unscheduled inspections and field calls made when events required.

Maintenance Cost: Maintenance costs are categorized under the subheadings of scheduled and unscheduled maintenance, vandalism, acts of God, landscape maintenance and other private contractors. Scheduled and unscheduled maintenance typically include irrigation, removal of standing water, removal of sediment, removal of trash, removal of debris, landscape management, management of structural integrity, pump servicing, cleaning of filters and graffiti removal. Costs to make repairs on vandalized BMP equipment were tracked as maintenance. Acts of God include costs for repairs to BMP devices damaged by severe weather, earthquakes or other acts of nature. Maintenance costs include hiring private contractors to provide maintenance of landscaped areas or other specialty services.

Vector Control Cost: Costs for vector abatement and control are indicated under the subheadings of Contract and General Administration, Vector Prevention Maintenance, Response to Vector Control District (VCD) calls, and VCD Efforts. Private firms were hired for installation of prevention devices, maintenance of vector populations, and response to VCD calls. General administration costs are a result of office work generated by contracts for consultant and contractor vector control projects that are administered and managed by agency personnel. Costs for vector prevention maintenance, response to VCD calls, and VCD efforts are direct costs generated by the contract work.

Equipment Cost: Costs for the time the equipment is allocated to the BMP not just the time the equipment is operated in the field.

Direct Costs: These costs include VCD supplies, reproduction and postage, field supplies and minor equipment (shovels, gloves, etc.), miscellaneous equipment rental, sediment analysis, sediment disposal, and miscellaneous other direct costs.

Total O&M Cost: Total of all O&M costs less the administrative costs for the 10 months of recordation (October 1999 through July 2000).

Annual O&M Cost: Total O&M costs adjusted to an annual amount.

Tributary Drainage Area: As defined in Section II.D.

Water Quality Design Discharge: As defined in Section II.D.

Water Quality Design Volume: As defined in Section II.D.

Annual O&M Unit Cost: The annual O&M of the BMP installation per water quality design unit (Annual O&M Cost divided by Water Quality Design Volume/Discharge).

Annual O&M Unit Cost Bar Graph

The Annual O&M Unit Cost bar graph provides a graphical representation of the unit cost data from the O&M Unit Cost table by BMP installation. The x-axis identifies the WQ ID No. for the BMP installation. The y-axis shows the unit cost in dollars per water quality design unit. Each bar in the graph represents the Annual O&M Unit Cost for the indicated installation of that type of BMP in the Pilot Program.

Annual O&M Unit Cost Curves Graph

The Annual O&M Unit Cost Curves graph provides a graphical analysis of the unit cost data from the Annual O&M Unit Cost table. The x-axis shows the range of water quality design units. The y-axis shows the unit cost in dollars per water quality design unit. Based on the plotted unit costs, the cost curve illustrates the trends in the O&M unit cost over a range of water quality design units. The resulting curve equation is shown to the right of the chart.

Projected Annual O&M Costs Table

The Projected Annual O&M Costs table shows the derivation of the projected O&M unit costs for the BMP type for various water quality design units. The table contains the following information:

WQ ID No.: As defined in Section II.A.

Site Location: Typical site where the BMP type is constructed.

Projected Annual O&M Cost: For the indicated water quality design unit, the projected O&M cost for that type of BMP. This value is calculated using the appropriate curve equation from the Annual O&M Unit Cost Curve graph for each of the water quality design unit values.

Tributary Drainage Area: As defined in Section II.D.

Water Quality Design Discharge: The water quality design discharges for which projected O&M costs were developed. The selected water quality design discharges are representative of the BMP sizes in the Pilot Program and other volumes to show trends and project costs over a range of typical values.

Water Quality Design Volume: The water quality design volumes for which projected O&M costs were developed. The selected water quality design volumes are representative of the BMP sizes in the Pilot Program and other volumes to show trends and project costs over a range of typical values.

Projected Annual O&M Unit Cost: For the indicated water quality design unit, the projected O&M cost of the BMP device per water quality design unit (Projected O&M Cost divided by Water Quality Design Discharge/Volume).

Projected Annual O&M Unit Cost Bar Graph

The Projected Annual O&M Unit Cost bar graph provides a graphical representation of the projected O&M unit cost data from the Projected O&M Cost table in ascending order by water quality design unit. The x-axis shows the water quality design units (volumes/discharges). The y-axis shows the unit cost in dollars per water quality design unit. Each bar in the graph represents the Projected Annual O&M Unit Cost to construct that type of BMP at that water quality design unit.

Projected Annual O&M Cost Bar Graph

The Projected Annual O&M Cost bar graph provides a graphical representation of the projected annual O&M cost data from the Projected Annual O&M Cost table. The x-axis shows the water quality design units (acre ft. or cfs) in ascending order. The y-axis shows the projected annual O&M cost for that type of BMP for that water quality design unit. Each bar in the graph represents the Projected Annual O&M Cost for that type of BMP for that water quality design unit.

1. Extended Detention Basin – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the extended detention basin (EDB) BMP type. Table 1-A presents the annual O&M unit costs for the five EDBs constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the EDB are specified by volume in acre-ft.

For the five EDB installations in the Pilot Program, the Annual O&M Unit Costs ranged from $1,933 to $145,269 per acre-foot, as shown in Graph 1-1.

The trend, as shown by the cost curve in Graph 1-2, indicates the annual O&M unit costs are projected to decrease as water quality design volume increases.

Table 1-B shows projected annual O&M cost data derived using the cost curve equation from Graph 1-2 for 14 different water quality design volumes; the five associated with the Pilot Program installations, and nine additional volumes representing a typical range of values. The data are listed in ascending order by water quality design volume.

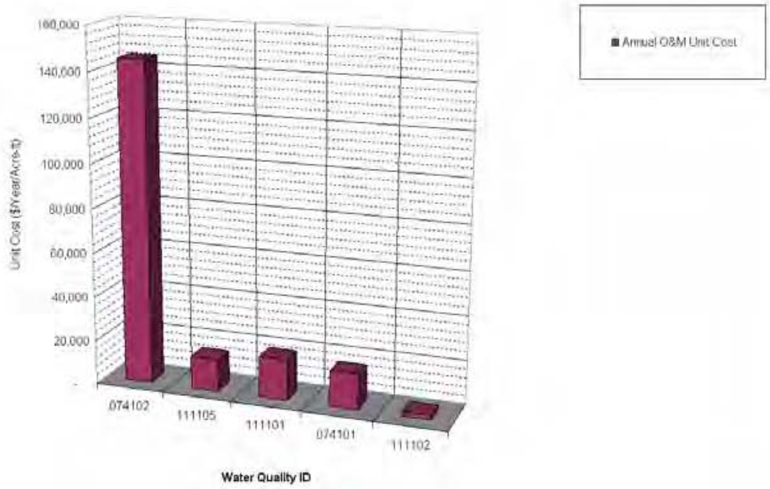
For the 14 water quality design volumes in the table, the Projected Annual O&M Unit Costs ranged from $1,145 to $124,752, as shown in Graph 1-3. The graph shows that unit cost decreases as design volume increases.

Graph 1-4 graphically represents the Projected Annual O&M Cost data from Table 1-B in ascending order by water quality design volume. This graph shows the decrease in the total projected O&M cost of an EDB device as the water quality design volume increases. This is a trend that was unexpected and may not be realized in the future.

TABLE 1-A. ANNUAL O&M UNIT COSTS - EDBs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/Acre-ft)
Extended Detention Basins														
074102	EDB	I-605/SR 91 Intersection	5,430	529	3,138	3,361	29	1,417	8,474	10,169	0.80	1.10	0.07	145,269
111105	EDB	I-5/Manchester (east)	3,940	550	603	617	-	648	2,418	2,902	4.80	4.63	0.20	14,508
111101	EDB	I-5/SR 56	4,010	605	1,842	1,607	-	872	4,926	5,911	5.30	5.72	0.32	18,473
074101	EDB	I-5/I-605 Intersection	5,498	506	1,815	3,768	101	1,493	7,683	9,220	6.40	5.20	0.57	16,175
111102	EDB	I-15/SR 78	2,933	578	83	606	-	199	1,466	1,759	13.50	9.50	0.91	1,933

GRAPH 1-1. Annual O&M Unit Cost - EDBs



GRAPH 1-2. Annual O&M Unit Cost Curve - EDBs

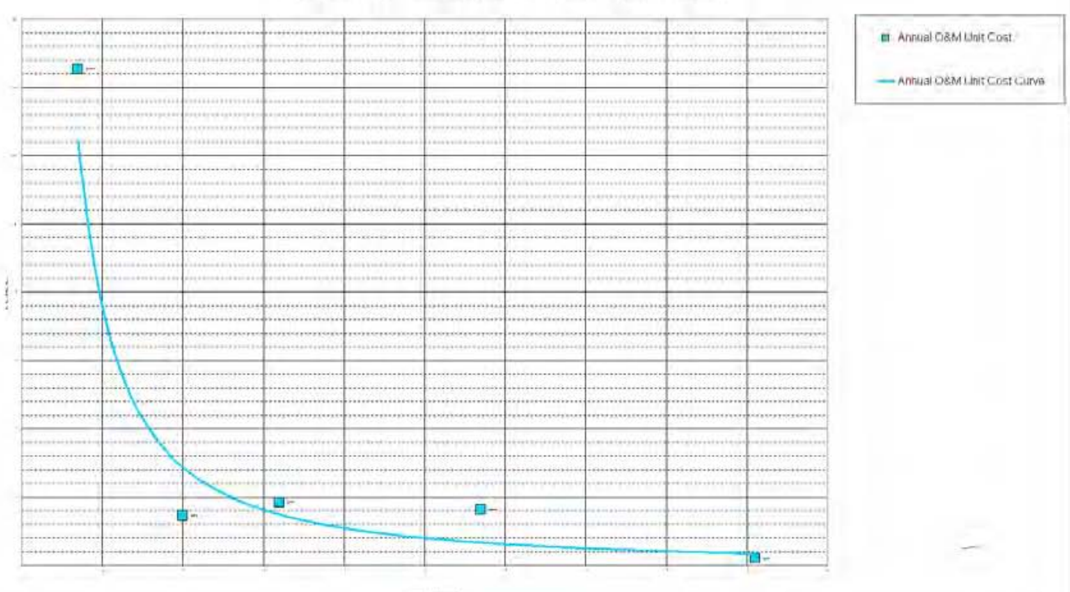
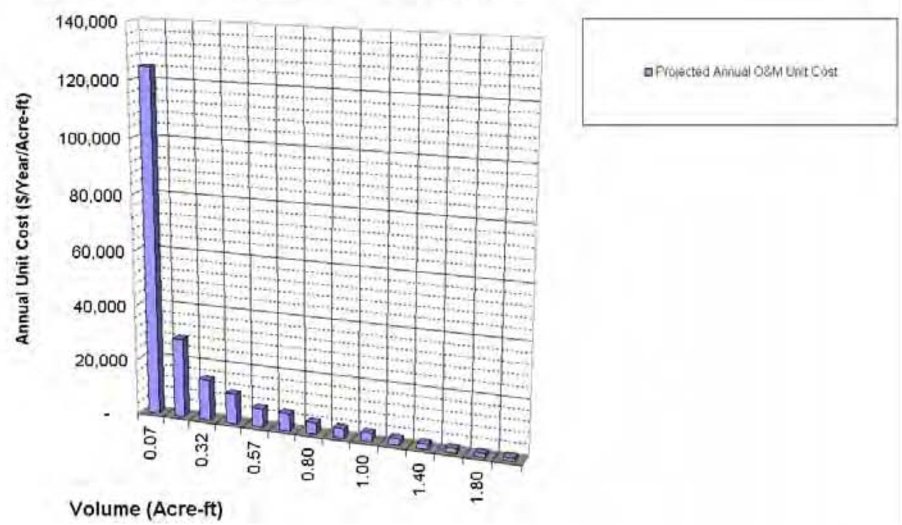


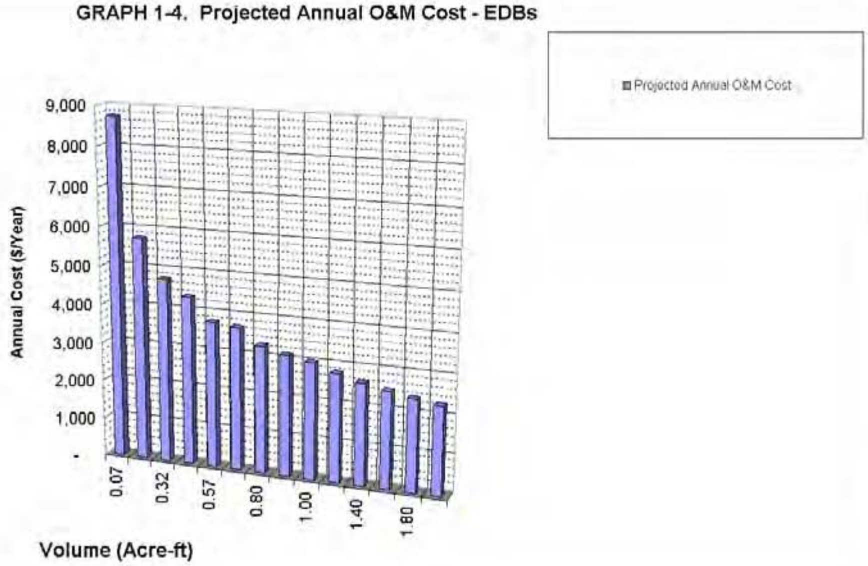
TABLE 1-B. PROJECTED ANNUAL O&M COSTS - EDBs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/Acre-ft)
Extended Detention Basins						
74102	Typical Sites with Indicated Water Quality Volume	8,733			0.07	124,752
111105		5,742			0.20	28,712
111101		4,760			0.32	14,874
		4,354			0.40	10,885
74101		3,780			0.57	6,631
		3,703			0.60	6,172
		3,301			0.80	4,127
111102		3,136			0.91	3,446
		3,020			1.00	3,020
		2,808			1.20	2,340
		2,640			1.40	1,886
		2,503			1.60	1,564
		2,388			1.80	1,327
		2,290			2.00	1,145

GRAPH 1-3. Projected Annual O&M Unit Cost - EDBs



GRAPH 1-4. Projected Annual O&M Cost - EDBs



2. Media Filter (Austin Sand Filter) – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Media Filter - Austin Sand Filter (MFSA) BMP type. Table 2-A presents the annual O&M unit costs for five MFSA devices constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the MFSA are specified by discharge in cfs. There were six MFSA installations as part of the Pilot Program, but only five installations were included in this analysis due to lack of available data for one installation.

For the five MFSA installations analyzed from the Pilot Program, the Annual O&M Unit Costs ranged from $1,426 to $4,603 per cfs, as shown in Graph 2-1.

The trend, as shown by the cost curve in Graph 2-2, indicates the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 2-B shows projected cost data derived using the cost curve equation from Graph 2-2 for 12 different water quality design discharges; the five associated with the Pilot Program installations, and seven additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

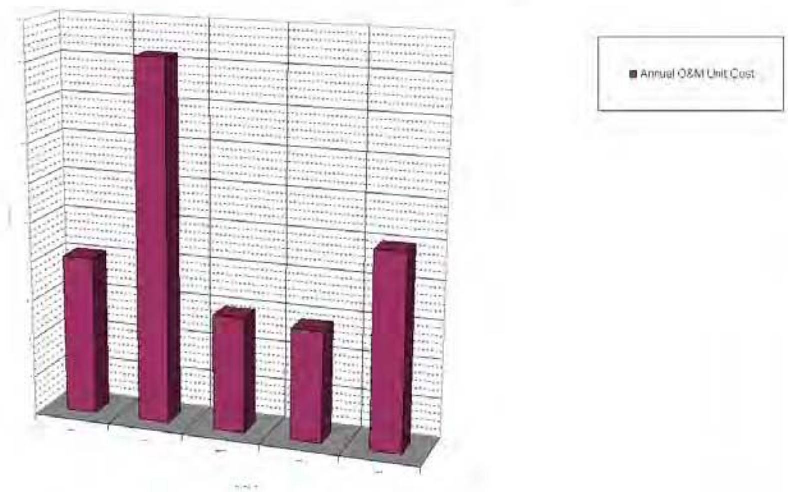
For the 12 water quality design discharges in the table, the Projected Annual O&M Unit Costs ranged from $1,835 to $3,386, as shown in Graph 2-3. The graph shows that unit cost decreases as design volume increases.

Graph 2-4 graphically represents the Projected Annual O&M Cost data from Table 2-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost of constructing an MFSA as the water quality design discharge increases.

TABLE 2-A. ANNUAL O&M UNIT COSTS - MFSAs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Media Filter (Austin Sand Filter)														
112204	MFSA	SR 78/I-5 Park & Ride	2,700	550	303	1,167	-	199	2,219	2,663	0.80	1.31	0.09	2,037
074202	MFSA	Eastern Regional Maint. Sta.	5,828	518	1,159	3,764	-	1,463	6,904	8,285	1.50	1.80	0.09	4,603
1112203	MFSA	La Costa Park & Ride	2,558	523	674	1,387	-	199	2,783	3,340	2.70	2.26	0.19	1,478
074203	MFSA	Foothill Maint. Station	5,315	394	248	1,375	-	1,429	3,446	4,135	1.80	2.90	0.18	1,426
074204	MFSA	Termination Park & Ride	5,254	563	686	4,597	-	1,463	7,309	8,771	2.80	3.50	0.18	2,506

GRAPH 2-1. Annual O&M Unit Cost - MFSAs



GRAPH 2-2. Annual O&M Unit Cost Curve - MFSAs

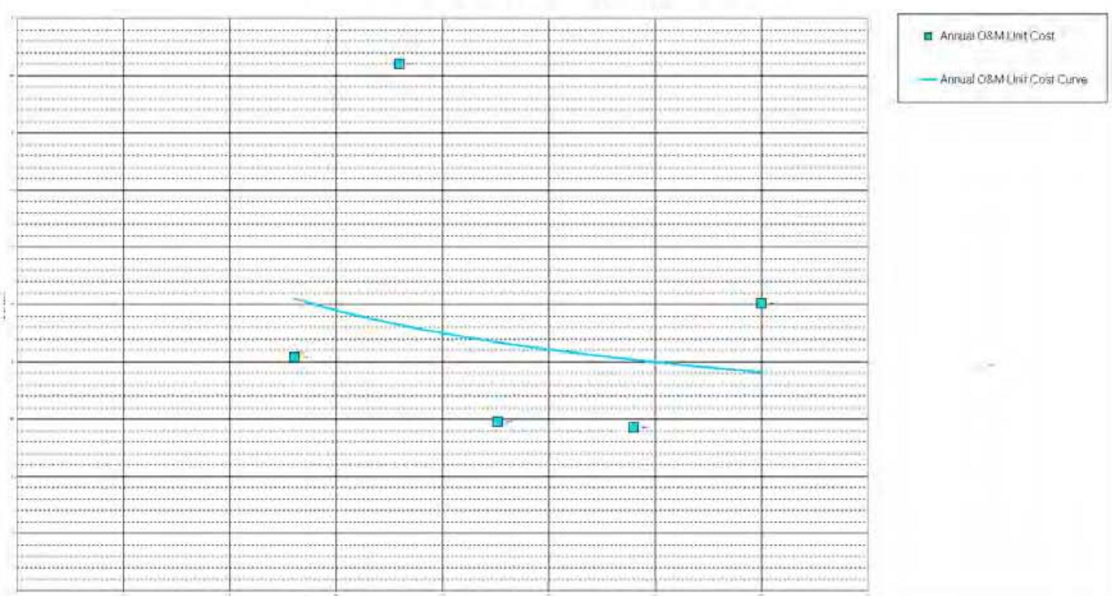
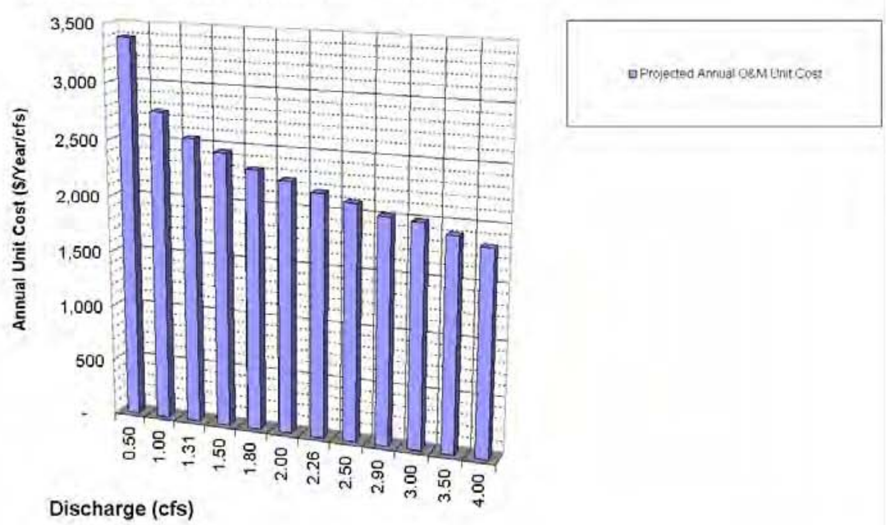


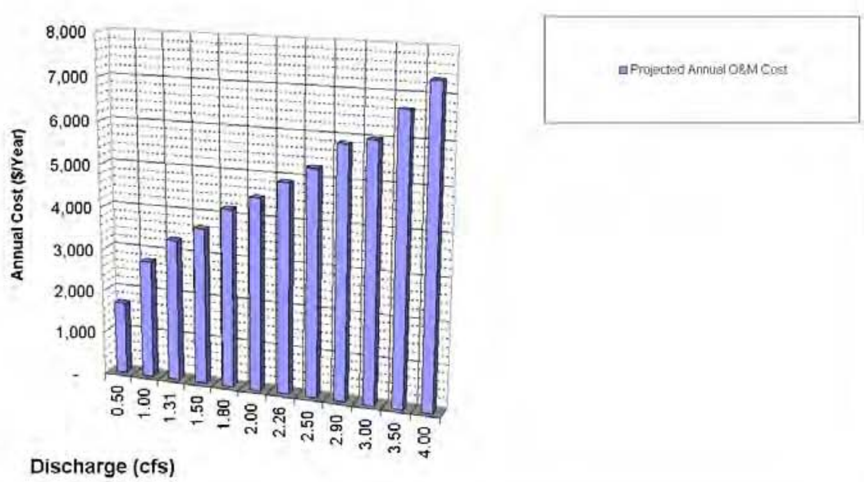
TABLE 2-B. PROJECTED ANNUAL O&M COSTS - MFSAs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Media Filter (Austin Sand Filter)						
	Typical Sites with Indicated Water Quality Discharge	1,693		0.50	-	3,386
		2,761		1.00	-	2,761
112204		3,334	0.80	1.31	0.09	2,551
		3,675		1.50	-	2,450
074202		4,179	1.50	1.80	0.09	2,322
		4,501		2.00	-	2,251
1112203		4,907	2.70	2.26	0.19	2,171
		5,269		2.50	-	2,107
074203		5,850	1.80	2.90	0.18	2,017
		5,992		3.00	-	1,997
074204		6,680	2.80	3.50	0.18	1,909
		7,340		4.00	-	1,835

GRAPH 2-3. Projected Annual O&M Unit Cost - MFSAs



GRAPH 2-4. Projected Annual O&M Cost - MFSAs



3. Media Filter (Delaware Sand Filter) – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Media Filter - Delaware Sand Filter (MFSD) BMP type. Annual O&M cost data for the MFSD device is shown in Table 3-A, listed in ascending order by water quality design size. Water quality design units for the MFSD are specified by discharge in cfs.

Only one MFSD was constructed as part of the Pilot Program. For this reason, the data for this one installation, and data derived from the MFSA analysis, were used to generate sufficient data to project annual O&M costs for the MFSD. Since the MFSD and MFSA are similar in general design and function, it is assumed that O&M costs of the two devices are likewise similar.

The Annual O&M Unit Cost data for the MFSD in Table 3-A were generated as follows:

- The Annual O&M Unit Cost for the one Pilot Program installation is used. In Table 3-A, this is identified by its WQ ID number.
- The MFSA Annual O&M Unit Cost Curve (Graph 2-2) was adjusted to pass through the MFSD Annual O&M Unit Cost for the Pilot Program installation. This resulted in an MFSA Curve Adjustment Factor of 0.47 (shown at the bottom of Table 3-A). This factor was then applied to the costs derived from the MFSA O&M Cost Curve for each discharge. The resulting Annual O&M Unit Costs are identified in Table 3-A by their discharge size in the WQ ID No. column.
- The "average" of the Annual O&M Unit Cost for all MFSDs constructed for the Pilot Program was calculated. In Table 3-A, this is identified as "Avg MFSD" in the WQ ID No. column. Since there was only one installation for the BMP type, the average Annual O&M Unit Cost is the same as the Annual O&M Unit Cost for the one installed BMP.

For the seven projected installations, the Annual O&M Unit Costs ranged from $905 to $1,210 per cfs, as shown in Graph 3-1.

The trend, as shown by the cost curve in Graph 3-2, indicates the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 3-B shows projected cost data derived using the cost curve equation from Graph 3-2 for 10 different water quality design discharges; the one associated with the Pilot Program installation, and nine additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

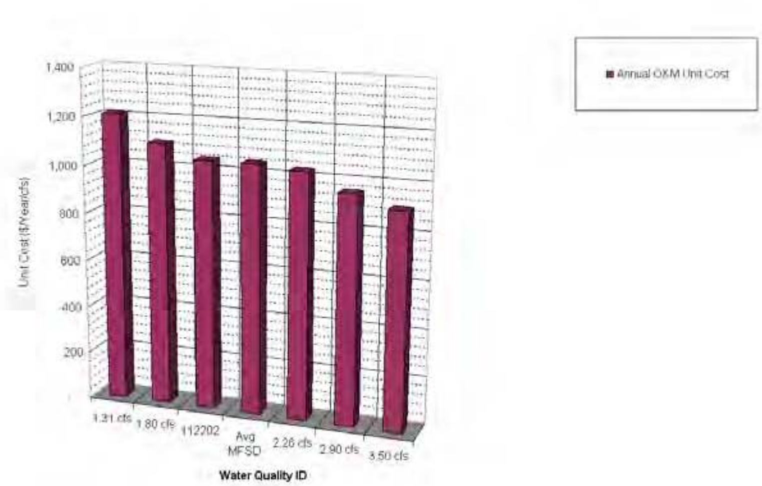
For the 10 water quality design discharges in the table, the Annual O&M Unit Costs ranged from $870 to $1,606 per cfs, as shown in Graph 3-3. The graph shows that unit cost decreases as design volume increases.

Graph 3-4 graphically represents the Projected Annual O&M Cost data from Table 3-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost of constructing an MFSD as the water quality design discharge increases.

TABLE 3-A. ANNUAL O&M UNIT COSTS - MFSDs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/Acre-ft)
Media Filter (Delaware Sand Filter)														
1.31 cfs									-	1,582		1.31		1,210
1.80 cfs									-	1,982		1.80		1,101
112202	MFSD	Escondido Maint. Station	2,732	564	-	1,112		199	1,875	2,250	0.80	2.15	0.30	1,045
Avg MFSD		Average							-	2,250		2.15		1,045
2.26 cfs									-	2,328		2.26		1,030
2.90 cfs									-	2,775		2.90		957
3.50 cfs									-	3,169		3.50		905
	MFSA Curve Adjustment Factor									0.47				
	Average MFSD									$ 2,250		2.15		

GRAPH 3-1. Annual O&M Unit Cost - MFSDs



GRAPH 3-2. Annual O&M Unit Cost Curve - MFSDs

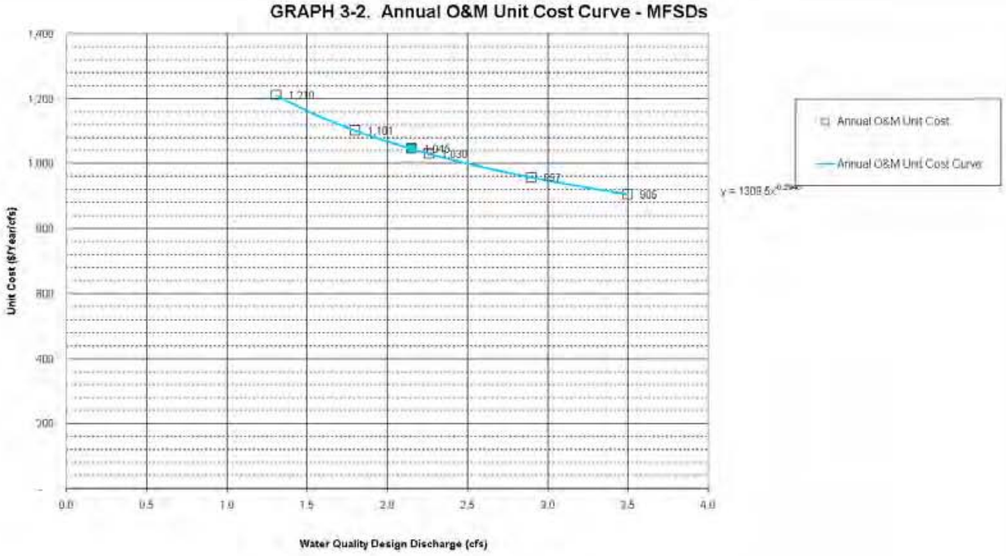
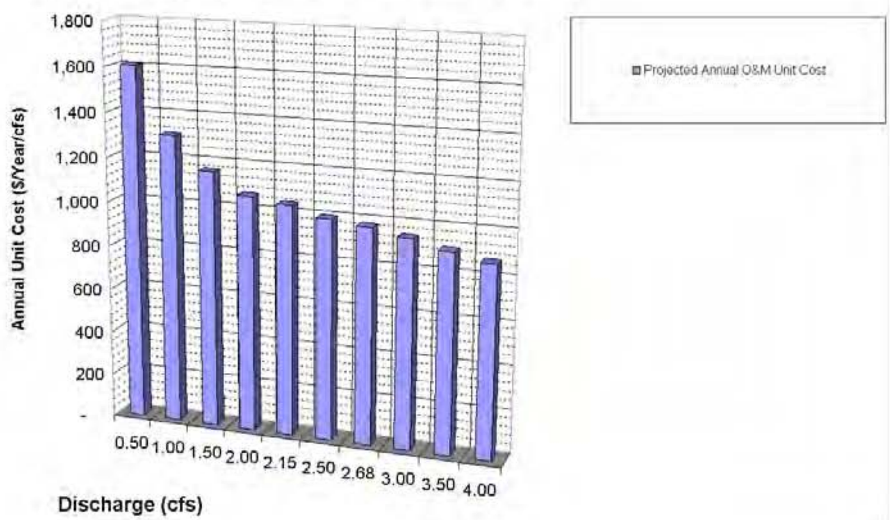


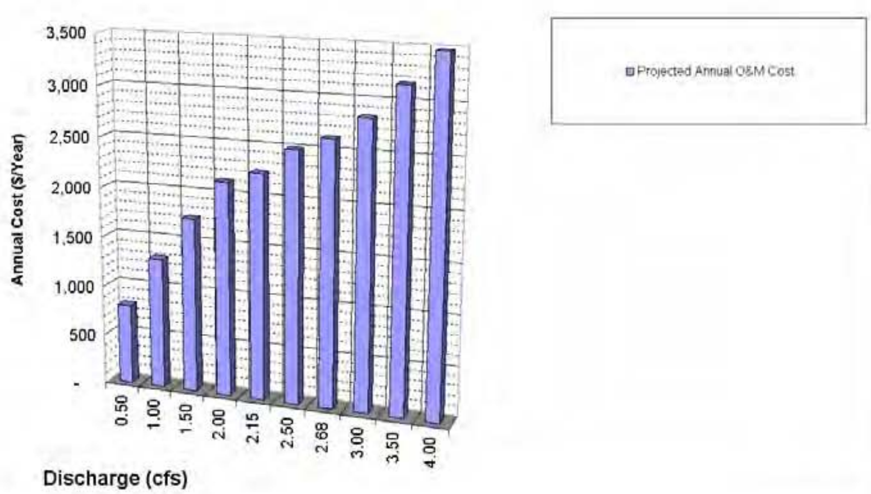
TABLE 3-B. PROJECTED ANNUAL O&M COSTS - MFSDs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Media Filter (Delaware Sand Filter)						
		803		0.50	-	1,606
		1,310		1.00	-	1,310
		1,743		1.50	-	1,162
		2,135		2.00	-	1,068
112202	Typical Sites with Indicated Water Quality Discharge	2,250	0.80	2.15	0.30	1,045
		2,499		2.50	-	1,000
		2,628		2.68	-	979
		2,842		3.00	-	947
		3,169		3.50	-	905
		3,482		4.00	-	870

GRAPH 3-3. Projected Annual O&M Unit Cost - MFSDs



GRAPH 3-4. Projected Annual O&M Cost - MFSDs



4. Multi-Chambered Treatment Train – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Multi-Chambered Treatment Train (MCTT) BMP type. Annual O&M cost data for the MCTT device is shown in Table 4-A, listed in ascending order by water quality design size. Water quality design units for the MCTT are specified by discharge in cfs.

Only two MCTT were constructed as part of the Pilot Program. For this reason, the data for these two installations, and data derived from the MFSA analysis, were used to generate sufficient data to project annual O&M costs for the MCTT. Since the MCTT and MFSA are similar in general design and function, it is assumed that construction of the two devices is likewise similar.

The Annual O&M Unit Cost data for the MCTT in Table 4-A were generated as follows:

- The Annual O&M Unit Costs for the two Pilot Program installations are used. In Table 4-A, these are identified by WQ ID number.
- The MFSA Annual O&M Unit Cost Curve (Graph 2-2) was adjusted to pass through the average of the two MCTT Annual O&M Unit Cost for the Pilot Program installation. This resulted in an MFSA Curve Adjustment Factor of 3.32 (shown at the bottom of Table 4-A). This factor was then applied to the costs derived from the MFSA O&M Cost Curve for each discharge. The resulting Annual O&M Unit Costs are identified in Table 4-A by their discharge size in the WQ ID No. column.
- The "average" of the Annual O&M Unit Cost for all MCTTs constructed for the Pilot Program was calculated. In Table 4-A, this is identified as "Avg MCTT" in the WQ ID No. column.

For the eight projected installations, the Annual O&M Unit Costs ranged from \$6,333 to \$8,466 per cfs, as shown in Graph 4-1.

The trend, as shown by the cost curve in Graph 4-2, indicates the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 4-B shows projected cost data derived using the cost curve equations from Graph 4-2 for 10 different water quality design discharges; the two associated with the Pilot Program installations, and eight additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

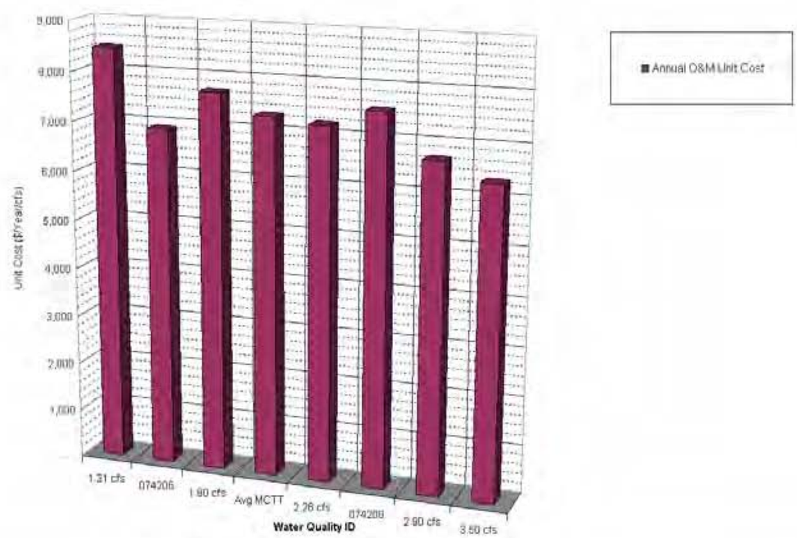
For the 10 water quality design discharges in the table, the Annual O&M Unit Costs ranged from \$6,389 to \$9,817 per cfs, as shown in Graph 4-3. The graph shows that unit cost decreases as design volume increases.

Graph 4-4 represents the Projected Annual O&M Cost data from Table 4-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost of constructing an MCTT as the water quality design discharge increases.

TABLE 4-A. ANNUAL O&M UNIT COSTS - MCTTs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/Acre-ft)
Multi-Chambered Treatment Train														
1.31 cfs									-	11,065		1.31		8,466
074206		Via Verde Park & Ride	7,434	709	1,384	4,371	-	2,744	9,208	11,050	1.10	1.60	0.10	6,906
1.80 cfs									-	13,867		1.80		7,704
Avg MCTT		Average							-	15,719		2.15		7,311
2.26 cfs									-	16,282		2.26		7,204
074208		Lakewood Park & Ride	8,284	1,735	3,931	8,537	-	2,787	16,990	20,388	1.93	2.70	0.14	7,551
2.90 cfs									-	19,413		2.90		6,694
3.50 cfs									-	22,167		3.50		6,333
	MFSA Curve Adjustment Factor									3.32				
	Average MCTT									$ 15,719		2.15		

GRAPH 4-1. Annual O&M Unit Cost - MCTTs



GRAPH 4-2. Annual O&M Unit Cost Curve - MCTTs

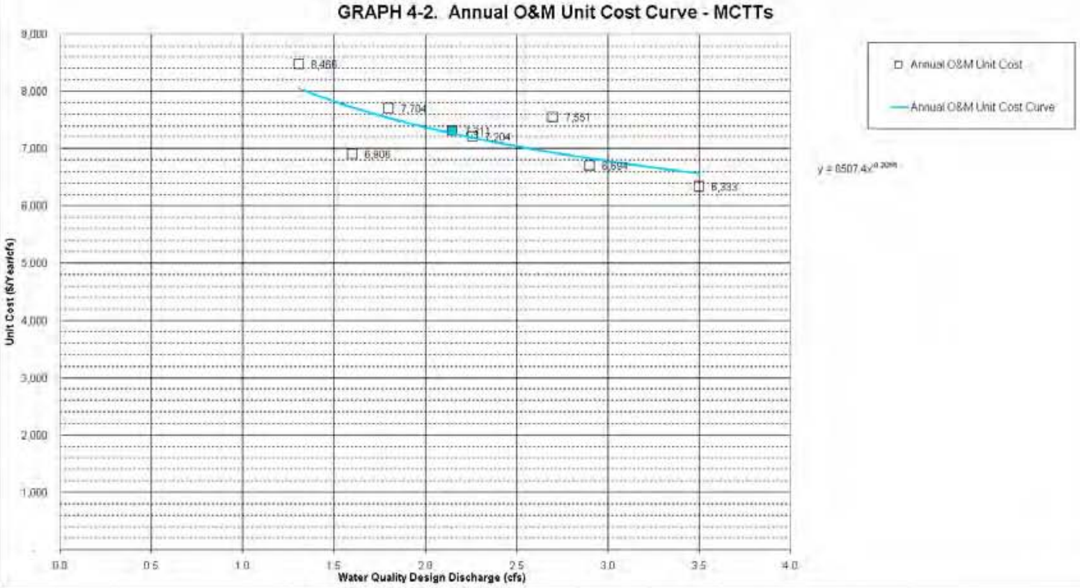
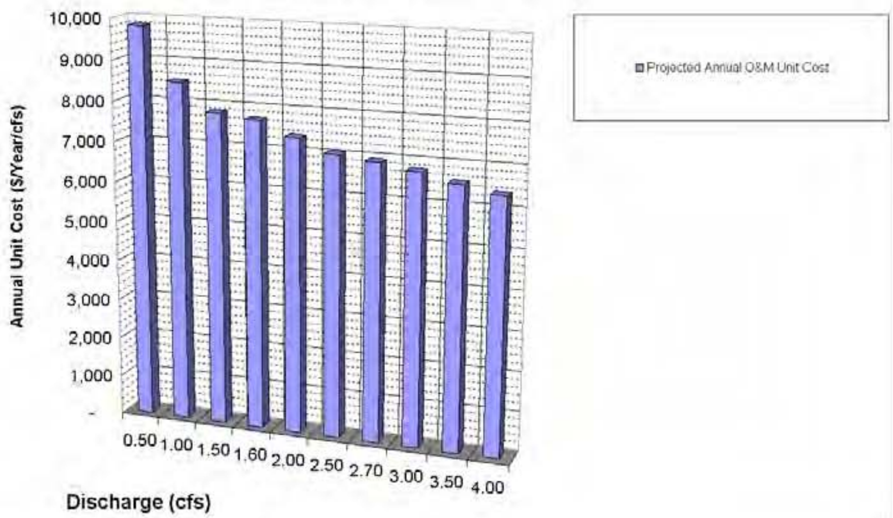


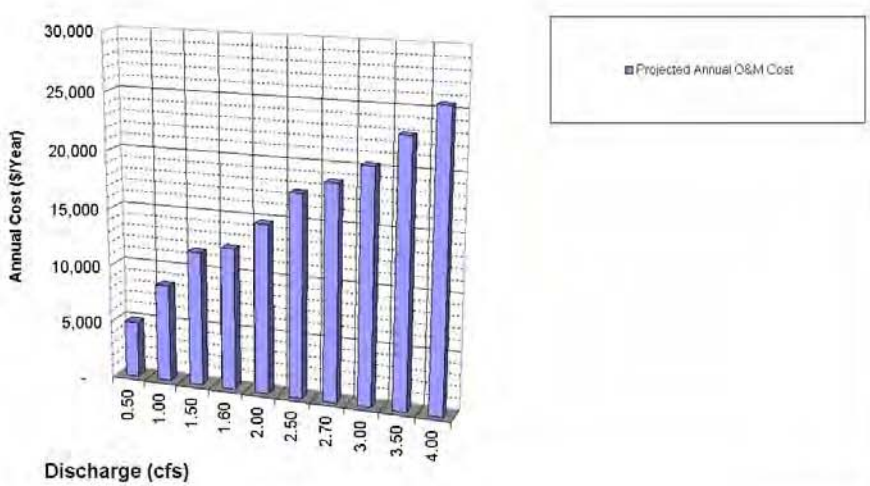
TABLE 4-B. PROJECTED ANNUAL O&M COSTS - MCTTs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Multi-Chambered Treatment Train						
	Typical Sites with Indicated Water Quality Discharge	4,909		0.50	-	9,817
		8,507		1.00	-	8,507
		11,736		1.50	-	7,824
074206		12,352	1.10	1.60	0.10	7,720
		14,745		2.00	-	7,372
		17,600		2.50	-	7,040
074208		18,709	1.93	2.70	0.14	6,929
		20,340		3.00	-	6,780
		22,986		3.50	-	6,567
		25,555		4.00	-	6,389

GRAPH 4-3. Projected Annual O&M Unit Cost - MCTTs



GRAPH 4-4. Projected Annual O&M Cost - MCTTs



5. Media Filter (StormFilter) – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Media Filter – Storm Filter (MFSTF) BMP type. Annual O&M cost data for the MFSTF device is shown in Table 5-A, listed in ascending order by water quality design size. Water quality design units for the MFSTF are specified by discharge in cfs.

Only one MFSTF was constructed as part of the Pilot Program. For this reason, the data for this one installation, and data derived from the MFSA analysis, were used to generate sufficient data to project annual O&M costs for the MFSTF. Since the MFSTF and MFSA are similar in general design and function, it is assumed that construction of the two devices is likewise similar.

The Annual O&M Unit Cost data for the MFSTF in Table 5-A were generated as follows:

- The Annual O&M Unit Costs for the two Pilot Program installations are used. In Table 5-A, these are identified by WQ ID number.
- The MFSA Annual O&M Unit Cost Curve (Graph 2-2) was adjusted to pass through the MFSTF Annual O&M Unit Cost for the Pilot Program installation. This resulted in an MFSA Curve Adjustment Factor of 0.61 (shown at the bottom of Table 5-A). This factor was then applied to the costs derived from the MFSA O&M Cost Curve for each discharge. The resulting Annual O&M Unit Costs are identified in Table 4-A by their discharge size in the WQ ID No. column.
- The "average" of the Annual O&M Unit Cost for all MFSTFs constructed for the Pilot Program was calculated. In Table 5-A, this is identified as "Avg MFSTF" in the WQ ID No. column. Since there was only one installation for the BMP type, the average Annual O&M Unit Cost is the same as the Annual O&M Unit Cost for the one installed BMP.

For the seven projected installations, the Annual O&M Unit Costs ranged from $1,168 to $1,563 per cfs, as shown in Graph 5-1.

The trend, as shown by the cost curve in Graph 5-2, indicates the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 5-B shows projected cost data derived using the cost curve equations from Graph 5-2 for nine different water quality design discharges; the one associated with the Pilot Program installation, and eight additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

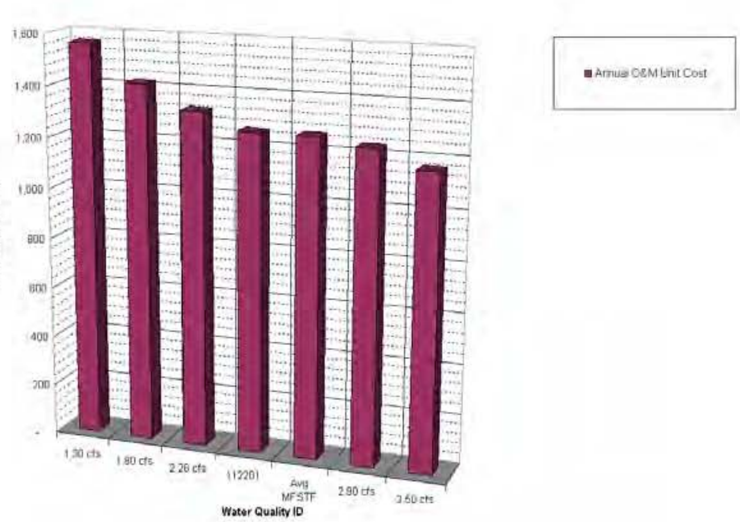
For the nine water quality design discharges in the table, the Annual O&M Unit Costs ranged from $1,123 to $2,072 per cfs, as shown in Graph 5-3. The graph shows that unit cost decreases as design volume increases.

Graph 5-4 represents the Projected Annual O&M Cost data from Table 5-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost of constructing an MFSTF as the water quality design discharge increases.

TABLE 5-A. ANNUAL O&M UNIT COSTS - MFSTFs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/Acre-ft)
Media Filter (Stormfilter)														
1.30 cfs									-	2,032		1.30	0.30	1,563
1.80 cfs									-	2,557		1.80	0.30	1,420
2.26 cfs									-	3,002		2.26	0.30	1,328
112201	MFSTF	Kearny Mesa Maint. Station	2,743	605	908	1,112	-	199	2,824	3,389	1.00	2.68	-	1,263
Avg MFSTF									-	3,389		2.68	0.30	1,263
2.90 cfs									-	3,579		2.90	0.30	1,234
3.50 cfs									-	4,087		3.50	0.30	1,168
	MFSA Curve Adjustment Factor									0.61				
	Average MFSTF									$ 3,389		2.68		

GRAPH 5-1. Annual O&M Unit Cost - MFSTFs



GRAPH 5-2. Annual O&M Unit Cost Curve - MFSTFs

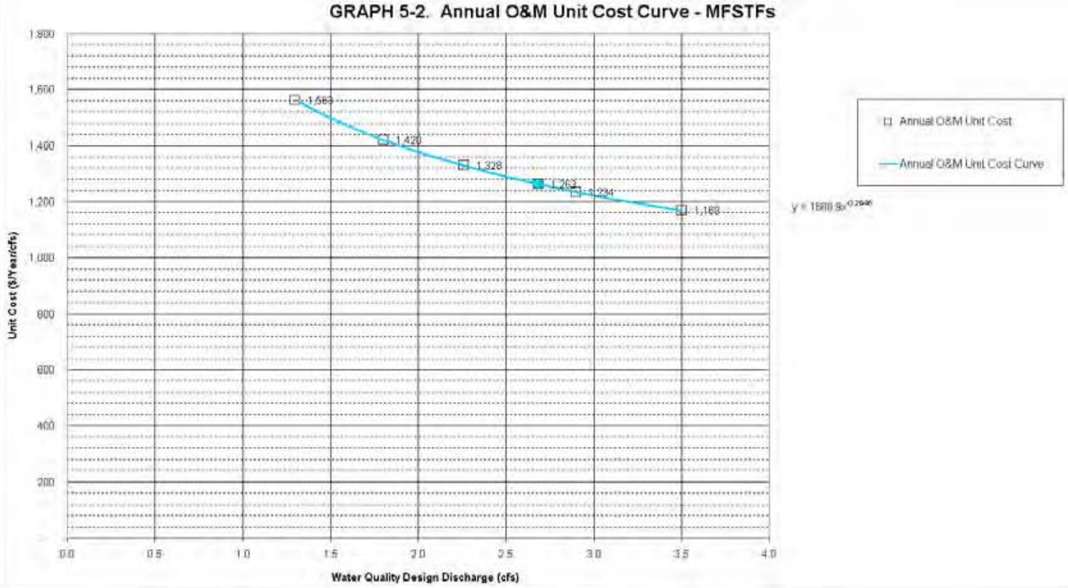
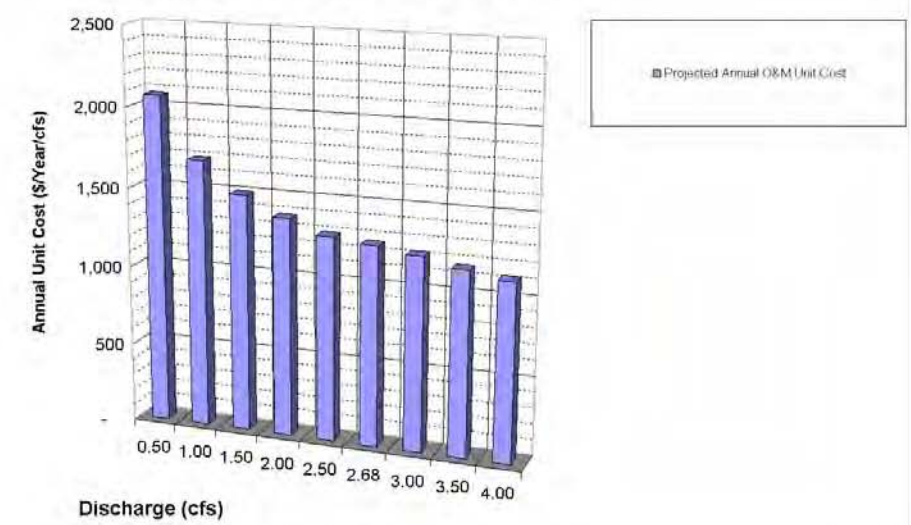


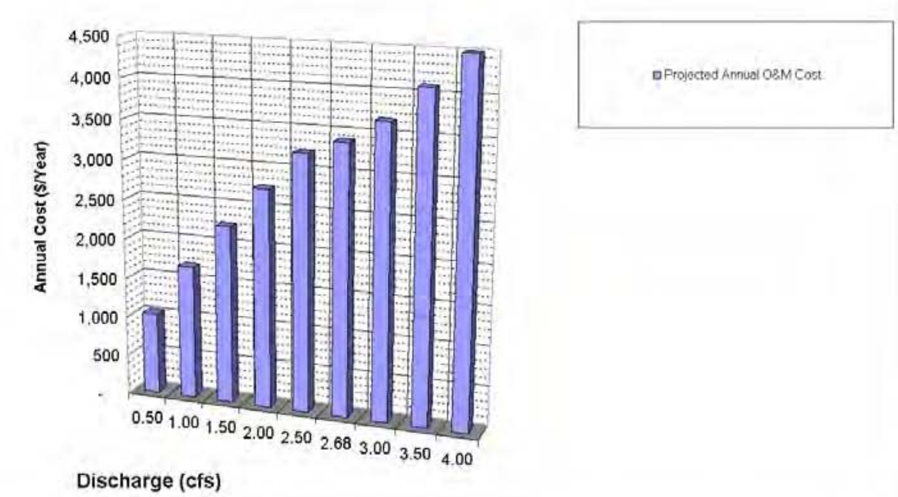
TABLE 5-B. PROJECTED ANNUAL O&M COSTS - MFSTFs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Media Filter (Stormfilter)						
	Typical Sites with Indicated Water Quality Discharge	1,036		0.50	-	2,072
		1,689		1.00	-	1,689
		2,248		1.50	-	1,499
		2,754		2.00	-	1,377
		3,223		2.50	-	1,289
112201		3,389	1.00	2.68	-	1,263
		3,666		3.00	-	1,222
		4,087		3.50	-	1,168
		4,491		4.00	-	1,123

GRAPH 5-3. Projected Annual O&M Unit Cost - MFSTFs



GRAPH 5-4. Projected Annual O&M Cost - MFSTFs



6. Biofiltration Swale – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Biofiltration Swale (BSW) BMP type. Table 6-A presents the annual O&M unit costs for six BSW devices constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the BSW are specified by discharge in cfs.

For the six BSW installations analyzed from the Pilot Program, the Annual O&M Unit Costs ranged from $4,591 to $194,931 per cfs, as shown in Graph 6-1.

The trend, as shown by the cost curve in Graph 6-2, indicates the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 6-B shows projected cost data derived using the cost curve equation from Graph 6-2 for 15 different water quality design discharges; the six associated with the Pilot Program installations, and nine additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

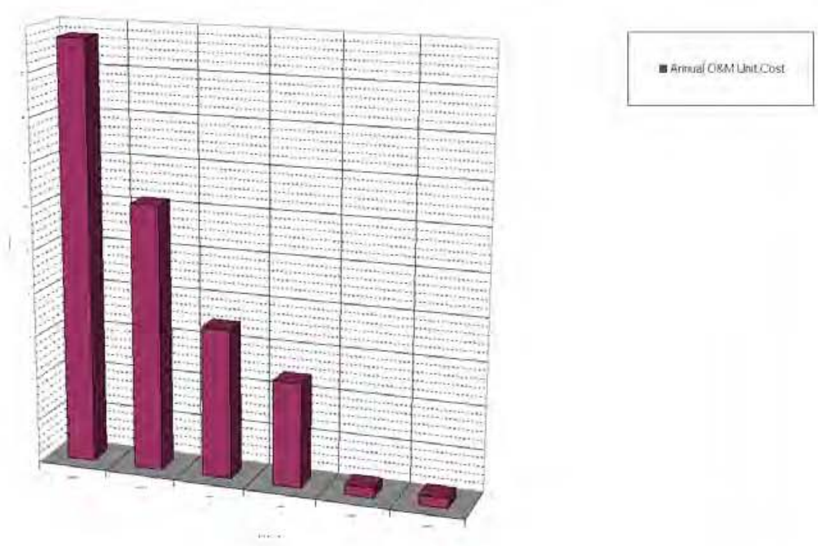
For the 15 water quality design discharges in the table, the Projected Annual O&M Unit Costs ranged from $3,955 to $234,510, as shown in Graph 6-3. The graph shows that unit cost decreases as design volume increases.

Graph 6-4 graphically represents the Projected Annual O&M Cost data from Table 6-B in ascending order by water quality design discharge This graph shows the decrease in the total projected O&M cost of an BSW device as the water quality design volume increases. This is a trend that was unexpected and may not be realized in the future.

TABLE 6-A. ANNUAL O&M UNIT COSTS - BSWs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Bio-Swales														
073222b	BSW	I-605/SR 91	16,376	651	7,105	603	171	2,841	11,371	13,645	0.80	0.07	-	194,931
073223	BSW	Cerritos Maint. Station	19,578	825	7,405	1,288	646	3,170	13,334	16,001	0.40	0.13	-	123,083
073225	BSW	I-605/Del Amo Ave	17,825	649	6,839	1,049	353	3,316	12,206	14,647	0.70	0.21	-	69,749
073224	BSW	I-5/1-605	15,719	662	4,834	1,102	114	3,837	10,549	12,659	0.65	0.26	-	48,688
112206	BSW	I-5/Palomar Airport Rd	3,322	550	1,957	1,549	106	2,323	6,485	7,782	2.30	1.66	-	4,688
112205	BSW	SR 78/Melrose Dr	4,120	553	2,779	1,029	50	2,257	6,668	8,002	2.30	1.74	-	4,591

GRAPH 6-1. Annual O&M Unit Cost - BSWs



GRAPH 6-2. Annual O&M Unit Cost Curve - BSWs

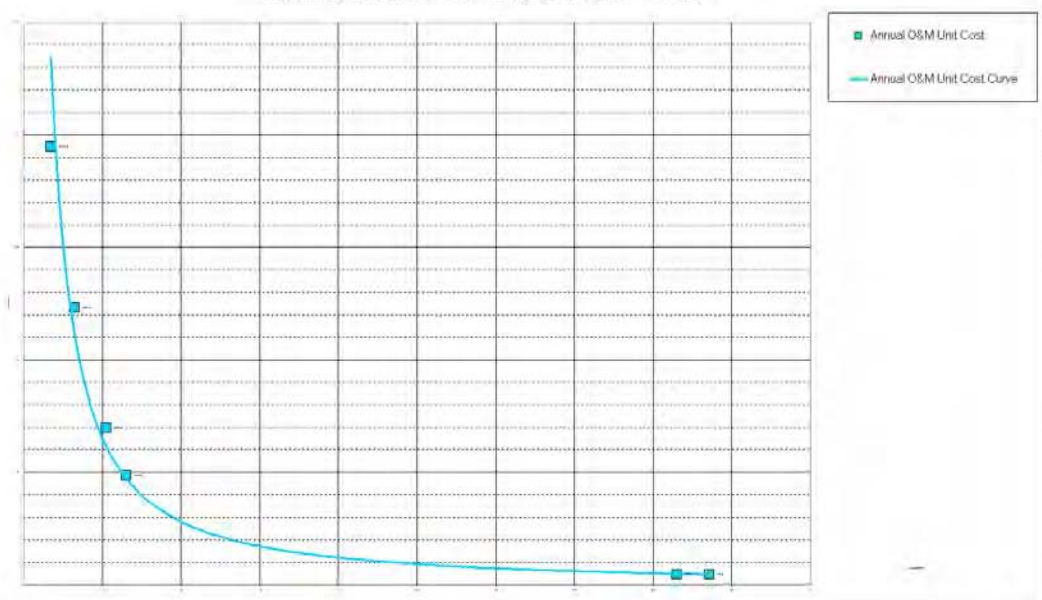
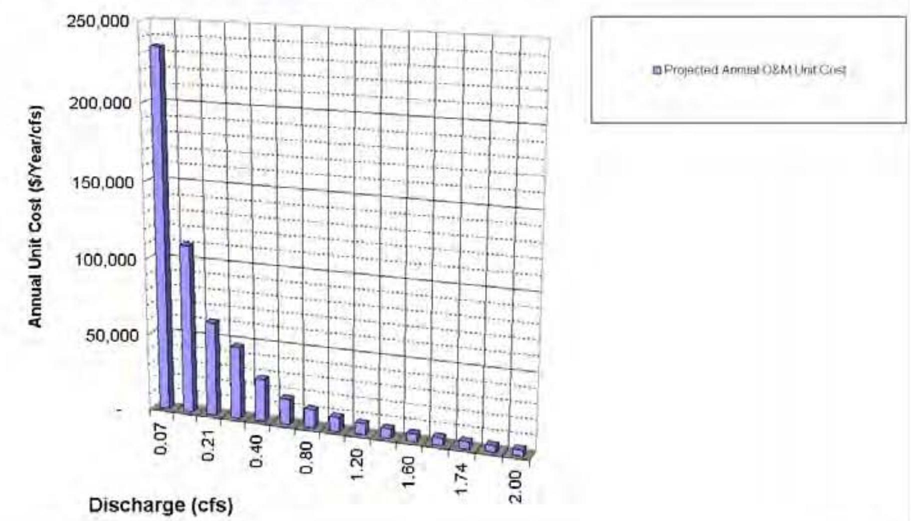


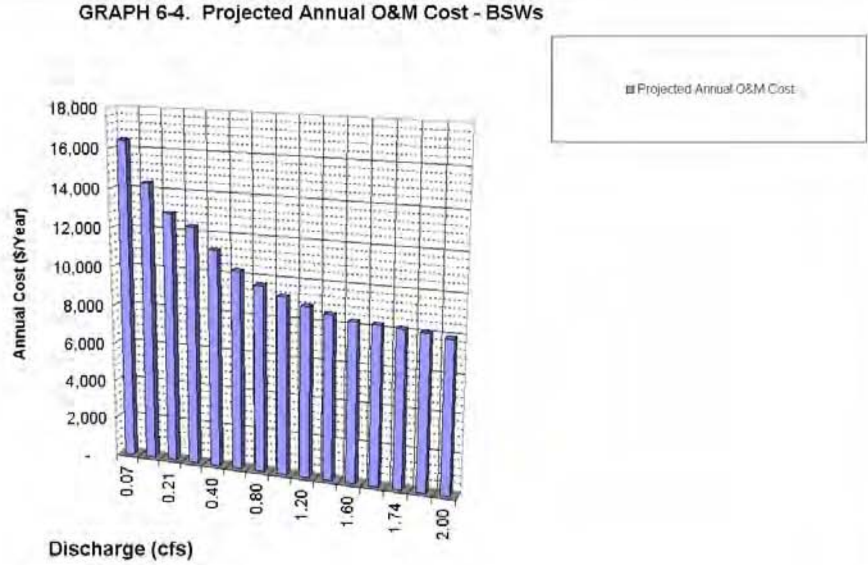
TABLE 6-B. PROJECTED ANNUAL O&M COSTS - BSWs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Bio-Swales						
073222b	Typical Sites with Indicated Water Quality Discharge	16,416	0.80	0.07	-	234,510
073223		14,345	0.40	0.13	-	110,347
073225		12,922	0.70	0.21	-	61,535
073224		12,335	0.65	0.26	-	47,442
		11,230		0.40	-	28,076
		10,281		0.60	-	17,135
		9,657		0.80	-	12,071
		9,199		1.00	-	9,199
		8,840		1.20	-	7,367
		8,549		1.40	-	6,106
		8,304		1.60	-	5,190
112206		8,237	2.30	1.66	-	4,962
112205		8,150	2.30	1.74	-	4,676
		8,093		1.80	-	4,496
		7,910		2.00	-	3,955

GRAPH 6-3. Projected Annual O&M Unit Cost - BSWs



GRAPH 6-4. Projected Annual O&M Cost - BSWs



7. Biofiltration Strip – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Biofiltration Strip (BSTRP) BMP type. Table 7-A presents the annual O&M unit costs for three BSTRP devices constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the BSTRP are specified by discharge in cfs.

For the three BSTRP installations analyzed from the Pilot Program, the Annual O&M Unit Costs ranged from $9,363 to $144,737 per cfs, as shown in Graph 7-1.

The trend, as shown by the cost curve in Graph 7-2, indicates, the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 7-B shows projected cost data derived using the cost curve equation from Graph 7-2 for 12 different water quality design discharges; the three associated with the Pilot Program installations, and nine additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

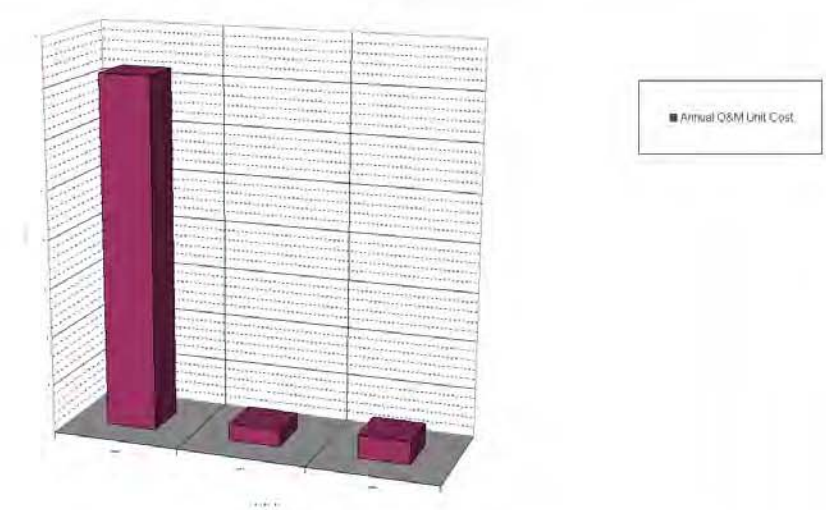
For the 12 water quality design discharges in the table, the Projected Annual O&M Unit Costs ranged from $2,567 to $114,559, as shown in Graph 7-3. The graph shows that unit cost decreases as design volume increases.

Graph 7-4 graphically represents the Projected Annual O&M Cost data from Table 7-B in ascending order by water quality design discharge. This graph shows the decrease in the total projected O&M cost of a BSTRP device as the water quality design volume increases. This is a trend that was unexpected and may not be realized in the future.

TABLE 7-A. ANNUAL O&M UNIT COSTS - BSTRPs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Bio-Strips														
073222a	BSTRP	I-605/SR 91	16,052	604	10,881	603	325	4,473	16,886	20,263	0.47	0.14	-	144,737
112207a	BSTRP	Carlsbad Maint. Station (west)	2,868	344	1,118	361	-	1,562	3,385	4,062	2.40	0.60	-	6,770
073211a	BSTRP	Altadena Maint. Station	14,046	745	5,662	671	94	1,879	9,051	10,861	1.66	1.16		9,363

GRAPH 7-1. Annual O&M Unit Cost - BSTRPs



GRAPH 7-2. Annual O&M Unit Cost Curve - BSTRPs

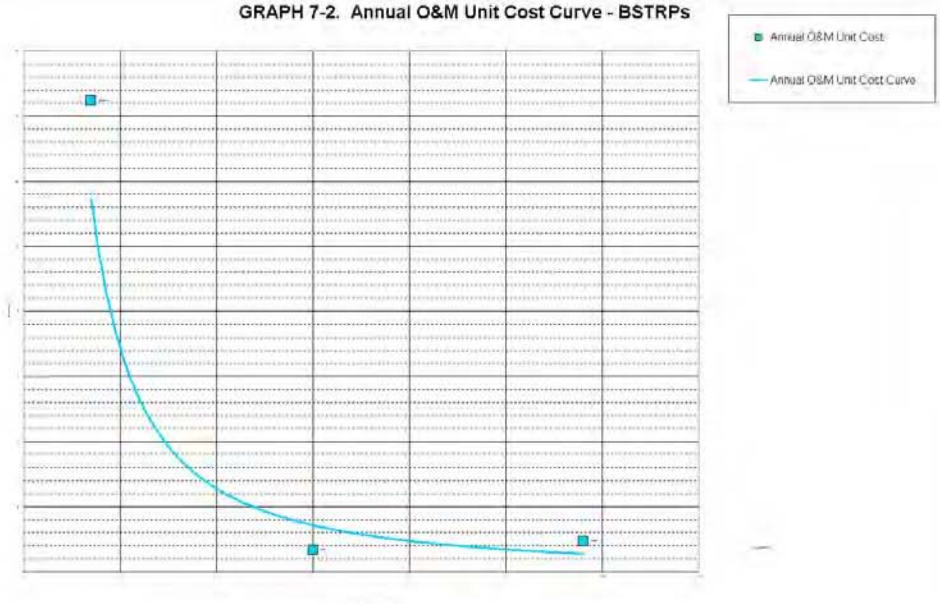
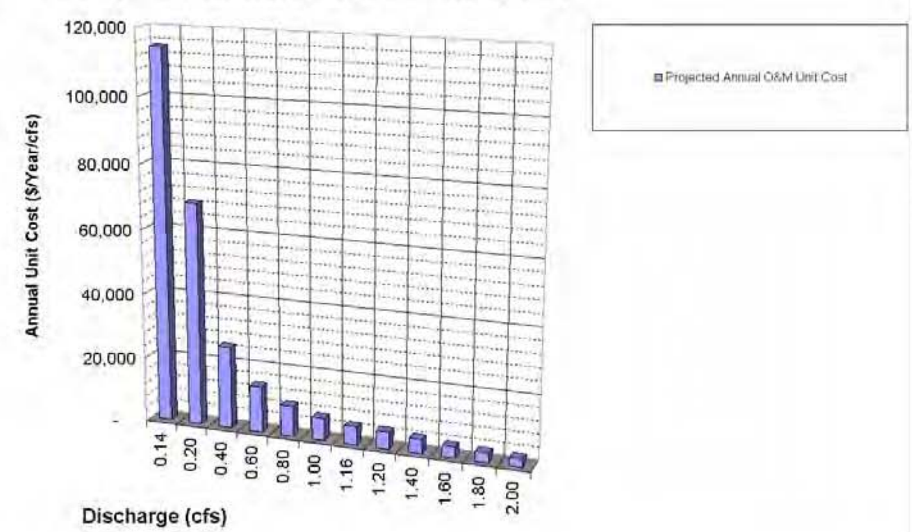


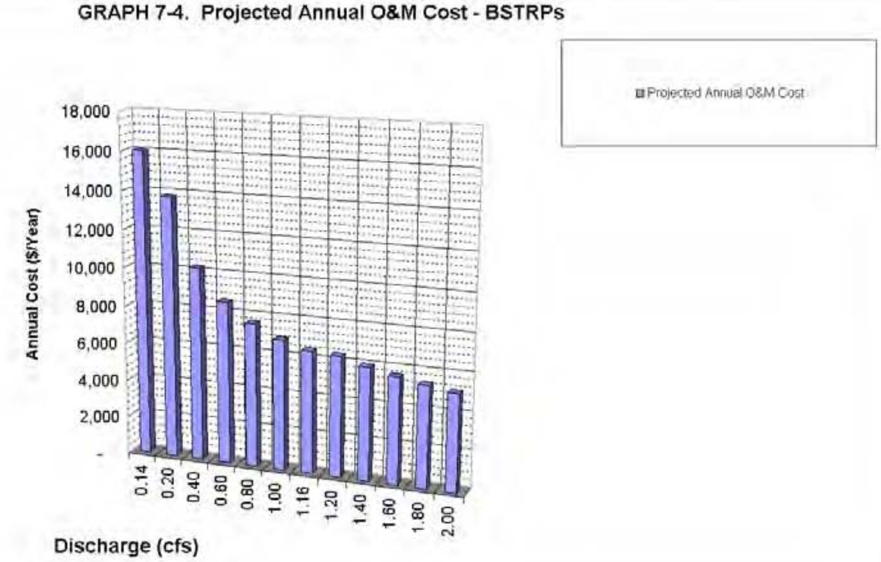
TABLE 7-B. PROJECTED ANNUAL O&M COSTS - BSTRPs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Bio-Strips						
073222a		16,038	0.47	0.14	-	114,559
		13,766		0.20	-	68,828
		10,229		0.40	-	25,573
112207a		8,598	2.40	0.60	-	14,330
		7,601		0.80	-	9,501
		6,908		1.00	-	6,908
073211a	Typical Sites with Indicated Water Quality Discharge	6,483	1.66	1.16	-	5,588
		6,389		1.20	-	5,324
		5,981		1.40	-	4,272
		5,648		1.60	-	3,530
		5,370		1.80	-	2,984
		5,133		2.00	-	2,567

GRAPH 7-3. Projected Annual O&M Unit Cost - BSTRPs



GRAPH 7-4. Projected Annual O&M Cost - BSTRPs



8. Infiltration Basin – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Infiltration Basin (IB) BMP type. Annual O&M cost data for the IB device is shown in Table 8-A, listed in ascending order by water quality design size. Water quality design units for the IB are specified by volume in acre-ft.

Only two IBs were constructed as part of the Pilot Program. For this reason, the data for these two installations, and data derived from the EDB analysis, were used to generate sufficient data to project annual O&M costs for the IB. Since the IB and EDB are similar in general design and function, it is assumed that O&M costs of the two devices are likewise similar.

The Annual O&M Unit Cost data for the IB in Table 8-A were generated as follows:

- The Annual O&M Unit Costs for the two Pilot Program installations are used. In Table 8-A, these are identified by WQ ID number.
- The EDB Annual O&M Unit Cost Curve (Graph 1-2) was adjusted to pass through the average of the two IB Annual O&M Unit Cost for the Pilot Program installation. This resulted in an EDB Curve Adjustment Factor of 0.79 (shown at the bottom of Table 8-A). This factor was then applied to the costs derived from the EDB O&M Cost Curve for each volume. The resulting Annual O&M Unit Costs are identified in Table 8-A by their volume size in the WQ ID No. column.
- The "average" of the Annual O&M Unit Cost for all IBs constructed for the Pilot Program was calculated. In Table 8-A, this is identified as "Avg IB" in the WQ ID No. column.

For the seven projected installations, the Annual O&M Unit Costs ranged from $10,376 to $224,551 per acre-ft, as shown in Graph 8-1.

The trend, as shown by the cost curve in Graph 8-2, indicates the annual O&M unit costs are projected to decrease as water quality design volume increases.

Table 8-B shows projected cost data derived using the cost curve equations from Graph 8-2 for 11 different water quality design volumes; the two associated with the Pilot Program installations, and nine additional volumes representing a typical range of values. The data are listed in ascending order by water quality design volume.

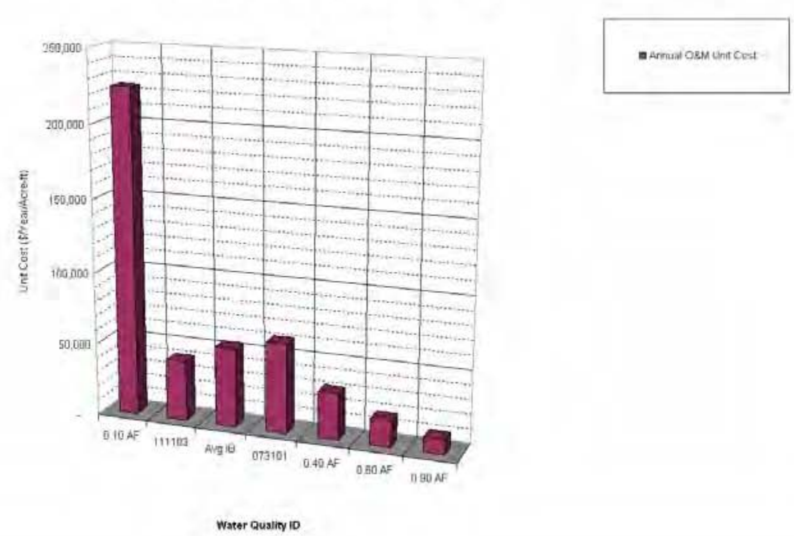
For the 11 water quality design volumes in the table, the Annual O&M Unit Costs ranged from $4,097 to $77,184 per acre-ft, as shown in Graph 8-3. The graph shows that unit cost decreases as design volume increases.

Graph 8-4 represents the Projected Annual O&M Cost data from Table 8-B in ascending order by water quality design volume. This graph shows the decrease in the total projected O&M cost of an IB device as the water quality design volume increases. This is a trend that was unexpected and may not be realized in the future.

TABLE 8-A. ANNUAL O&M UNIT COSTS - IBs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/Acre-ft)
Infiltration Basins														
0.10 AF										22,455			0.10	224,551
111103	IB	I-5/La Costa (west)	689	440	3,850	1,057	-	1,564	6,911	8,293	3.20	3.04	0.20	41,466
Avg IB		Average								14,993			0.28	54,520
073101	IB	I-605/SR 91	15,689	640	8,807	7,163	1,025	443	18,078	21,694	4.20	0.91	0.35	61,982
0.40 AF										12,910			0.40	32,274
0.60 AF										10,980			0.60	18,300
0.90 AF										9,339			0.90	10,376
	EDB Curve Adjustment Factor									2.96				
	Average IB									$ 14,993			0.28	

GRAPH 8-1. Annual O&M Unit Cost - IBs



GRAPH 8-2. Annual O&M Unit Cost Curve - IBs

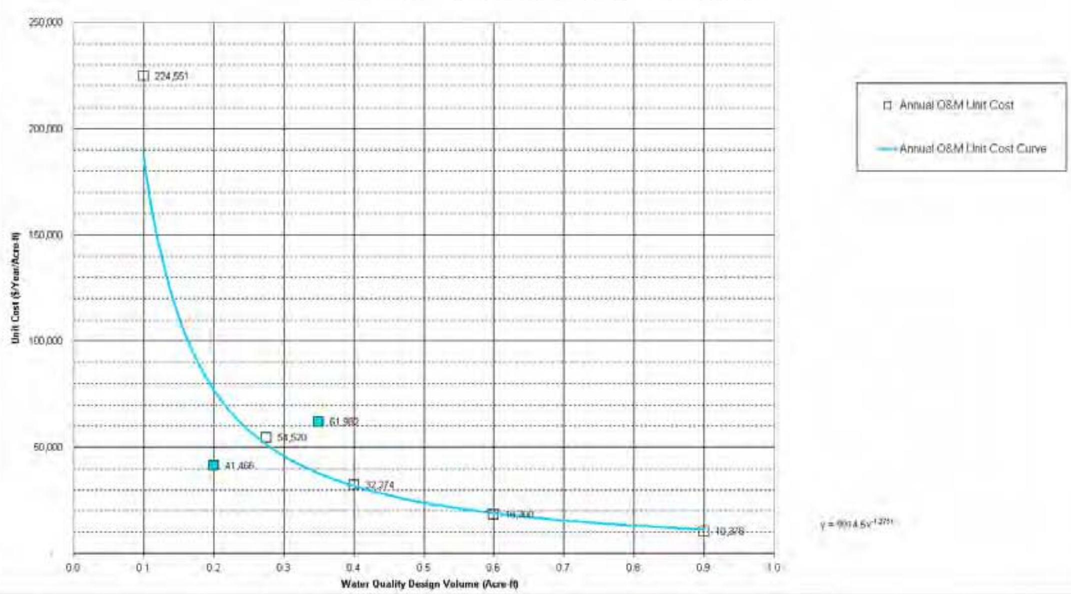
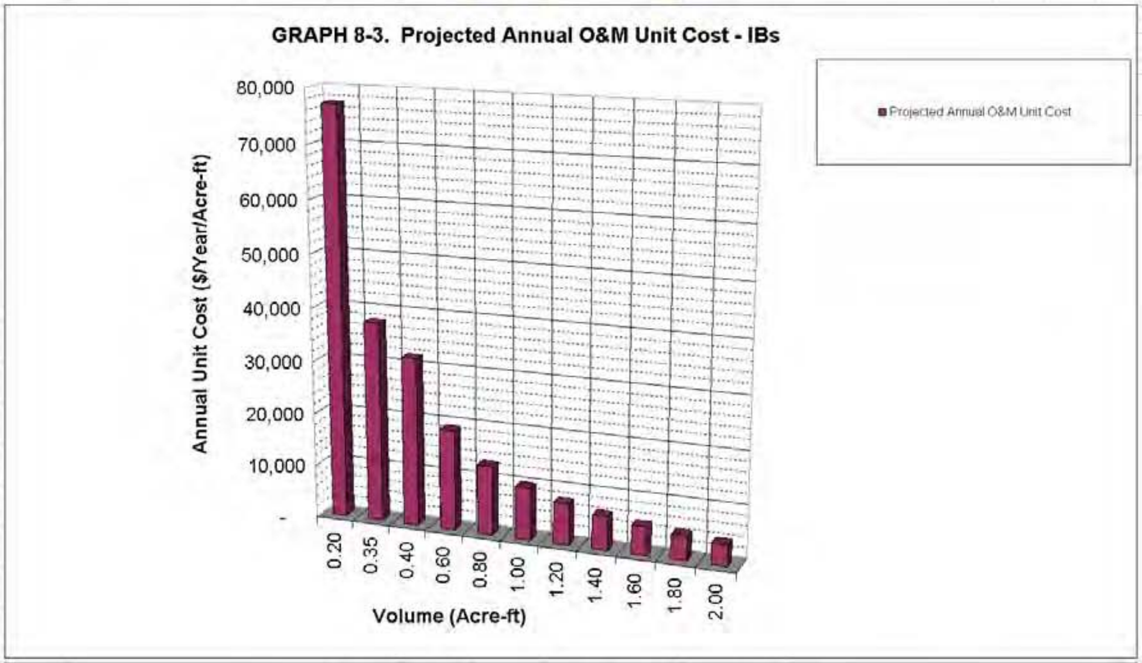
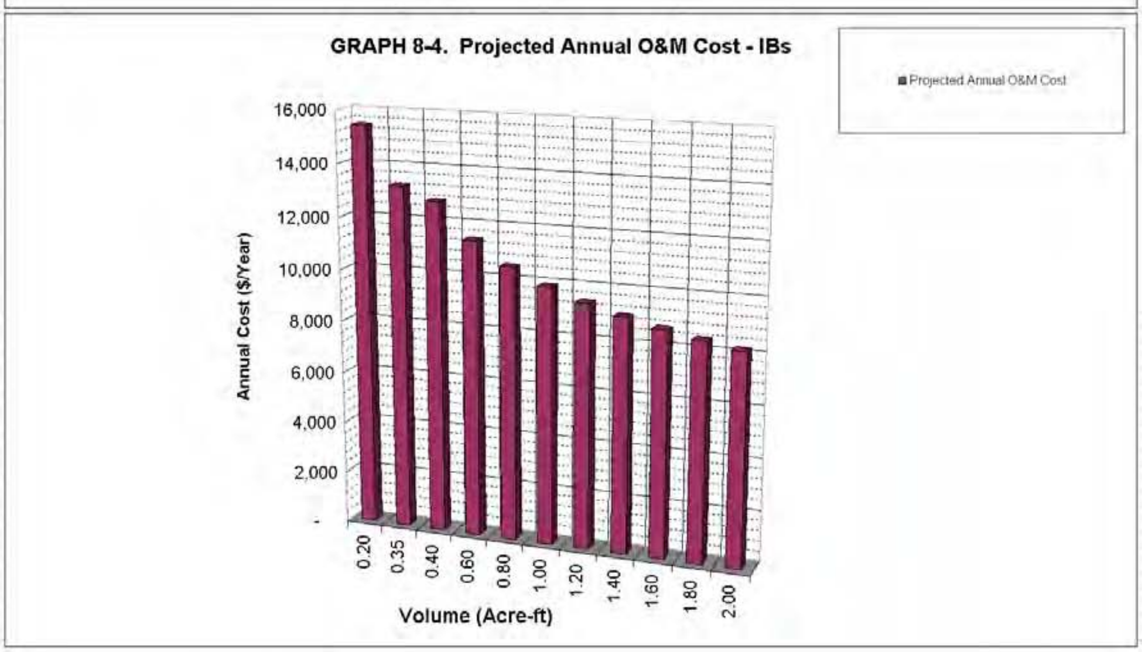


TABLE 8-B. PROJECTED ANNUAL O&M COSTS - IBs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/Acre-ft)
Infiltration Basins						
111103	Typical Sites with Indicated Water Quality Volume	15,437			0.20	77,184
73101		13,234			0.35	37,812
		12,757			0.40	31,892
		11,410			0.60	19,017
		10,542			0.80	13,178
		9,915			1.00	9,915
		9,429			1.20	7,858
		9,038			1.40	6,456
		8,712			1.60	5,445
		8,434			1.80	4,686
		8,193			2.00	4,097





9. Infiltration Trench/Strip – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Infiltration Trench/Strip (IT/STRP) BMP type. Annual O&M cost data for the IT/STRP device is shown in Table 9-A, listed in ascending order by water quality design size. Water quality design units for the IT/STRP are specified by discharge in cfs.

Only two IT/STRPs were constructed as part of the Pilot Program. For this reason, the data for these two installations, and data derived from the BSTRP analysis, were used to generate sufficient data to project annual O&M costs for the IT/STRP. Since the IT/STRP and BSTRP are similar in general design and function, it is assumed that O&M costs of the two devices are likewise similar.

The Annual O&M Unit Cost data for the IT/STRP in Table 9-A were generated as follows:

- The Annual O&M Unit Costs for the two Pilot Program installations are used. In Table 9-A, these are identified by WQ ID number.
- The BSTRP Annual O&M Unit Cost Curve (Graph 7-2) was adjusted to pass through the average of the two IT/STRP Annual O&M Unit Cost for the Pilot Program installation. This resulted in a BSTRP Curve Adjustment Factor of 1.88 (shown at the bottom of Table 9-A). This factor was then applied to costs derived from the BSTRP O&M Cost Curve for each discharge. The resulting Annual O&M Unit Costs are identified in Table 9-A by their discharge size in the WQ ID No. column.
- The "average" of the Annual O&M Unit Cost for all IT/STRPs constructed for the Pilot Program was calculated. In Table 8-A, this is identified as "Avg IT/STRP" in the WQ ID No. column.

For the six projected installations, the Annual O&M Unit Costs ranged from $8,157 to $214,836 per cfs, as shown in Graph 8-1.

The trend, as shown by the cost curve in Graph 9-2, indicates, the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 9-B shows projected cost data derived using the cost curve equations from Graph 9-2 for 12 different water quality design discharges; the two associated with the Pilot Program installations, and 10 additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

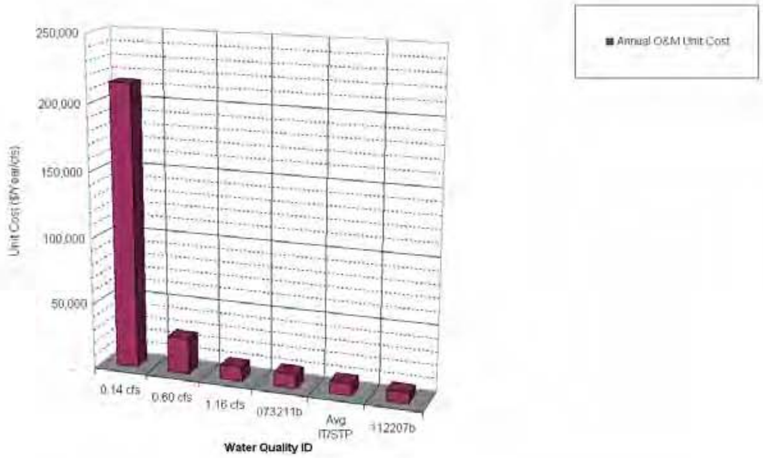
For the 12 water quality design discharges in the table, the Annual O&M Unit Costs ranged from $4,832 to $129,163 per cfs, as shown in Graph 9-3. The graph shows that unit cost decreases as design volume increases.

Graph 9-4 represents the Projected Annual O&M Cost data from Table 9-B in ascending order by water quality design discharge. This graph shows the decrease in the total projected O&M cost of an IT/STRP device as the water quality design volume increases. This is a trend that was unexpected and may not be realized in the future.

TABLE 9-A. ANNUAL O&M UNIT COSTS - IT/STRPs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Infiltration Trench/Bio-Strip														
0.14 cfs	BSTRP								-	30,077	0.47	0.14	-	214,836
0.60 cfs	BSTRP								-	16,124	2.40	0.60	-	26,874
1.16 cfs	BSTRP								-	12,157	1.66	1.16	-	10,480
073211b	IT/STRP	Altadena Maint. Station	10,513	578	41	623	-	499	1,741	12,417	1.66	1.16	0.14	10,704
Avg IT/STP		Average							-	11,700		1.27	-	9,223
112207b	IT/STRP	Carlsbad Maint. Station (east)	2,268	358	55	350	-	815	1,578	11,232	2.40	1.38	0.18	8,157
	BSTRP Curve Adjustment Factor									1.88				
	Average IT/STRP									$11,824		1.27		

GRAPH 9-1. Annual O&M Unit Cost - IT/STRPs



GRAPH 9-2. Annual O&M Unit Cost Curve - IT/STRPs

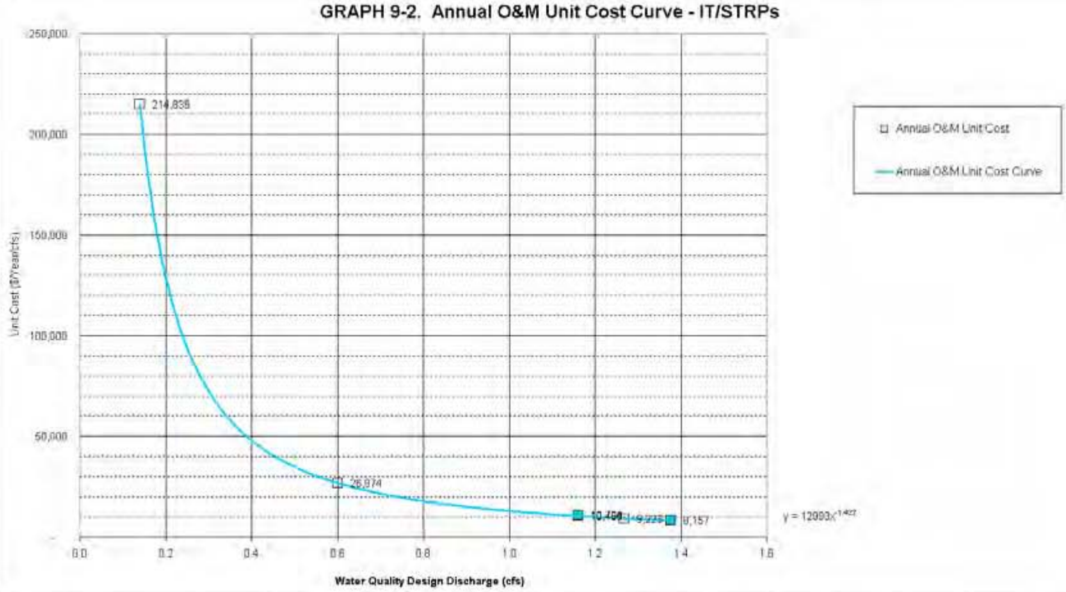
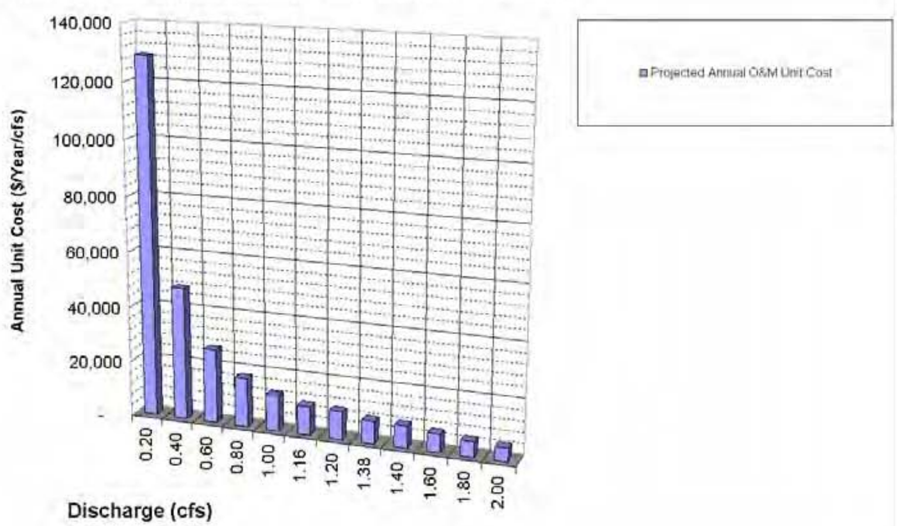


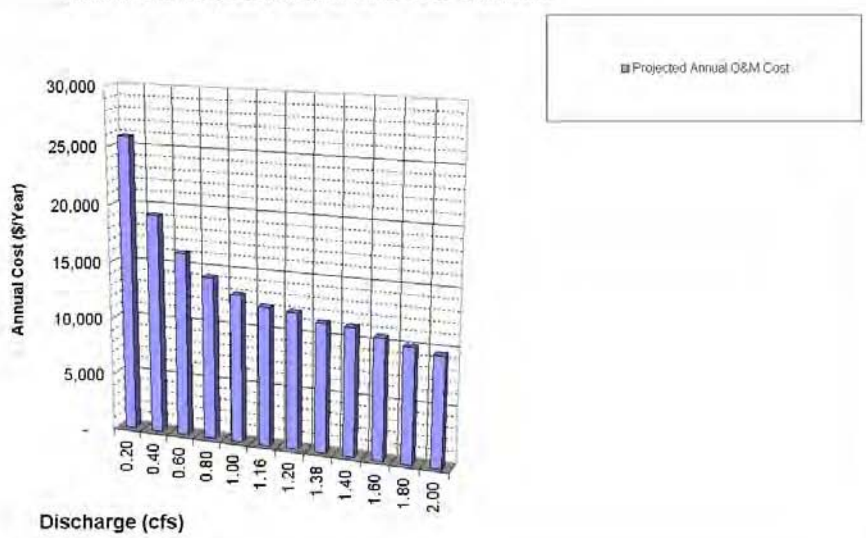
TABLE 9-B. PROJECTED ANNUAL O&M COSTS - IT/STRPs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Bio-Strips						
	Typical Sites with Indicated Water Quality Discharge	25,833		0.20	-	129,163
		19,215		0.40	-	48,036
		16,160		0.60	-	26,933
		14,292		0.80	-	17,865
		12,993		1.00	-	12,993
073211b		12,195	1.66	1.16	0.14	10,513
		12,020		1.20	-	10,017
112207b		11,334	2.40	1.38	0.18	8,231
		11,254		1.40	-	8,039
		10,630		1.60	-	6,644
		10,109		1.80	-	5,616
		9,664		2.00	-	4,832

GRAPH 9-3. Projected Annual O&M Unit Cost - IT/STRPs



GRAPH 9-4. Projected Annual O&M Cost - IT/STRPs



10. Wet Basin – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Wet Basin (WB) BMP type. Annual O&M cost data for the WB device is shown in Table 10-A, listed in ascending order by water quality design size. Water quality design units for the WB are specified by volume in acre-ft.

Only one WB was constructed as part of the Pilot Program. For this reason, the data for this one installation, and data derived from the EDB analysis, were used to generate sufficient data to project annual O&M costs for the WB. Since the WB and EDB are similar in general design and function, it is assumed that O&M costs of the two devices are likewise similar.

The Annual O&M Unit Cost data for the WB in Table 10-A were generated as follows:

- The Annual O&M Unit Costs for the one Pilot Program installations are used. In Table 10-A, these are identified by WQ ID number.
- The EDB Annual O&M Unit Cost Curve (Graph 1-2) was adjusted to pass through the WB Annual O&M Unit Cost for the Pilot Program installation. This resulted in an EDB Curve Adjustment Factor of 4.98 (shown at the bottom of Table 10-A). This factor was then applied to the costs derived from the EDB O&M Cost Curve for each volume. The resulting Annual O&M Unit Costs are identified in Table 10-A by their discharge size in the WQ ID No. column.
- The “average” of the Annual O&M Unit Cost for all WBs constructed for the Pilot Program was calculated. In Table 10-A, this is identified as “Avg WB” in the WQ ID No. column. Since there was only one installation for the BMP type, the average Annual O&M Unit Cost is the same as the Annual O&M Unit Cost for the one installed BMP.

For the eight projected installations, the Annual O&M Unit Costs ranged from $6,494 to $140,533 per acre-ft, as shown in Graph 10-1.

The trend, as shown by the cost curve in Graph 10-2, indicates the annual O&M unit costs are projected to decrease as water quality design volume increases.

Table 10-B shows projected cost data derived using the cost curve equations from Graph 10-2 for 10 different water quality design volumes; the one associated with the Pilot Program installation, and nine additional volumes representing a typical range of values. The data are listed in ascending order by water quality design volume.

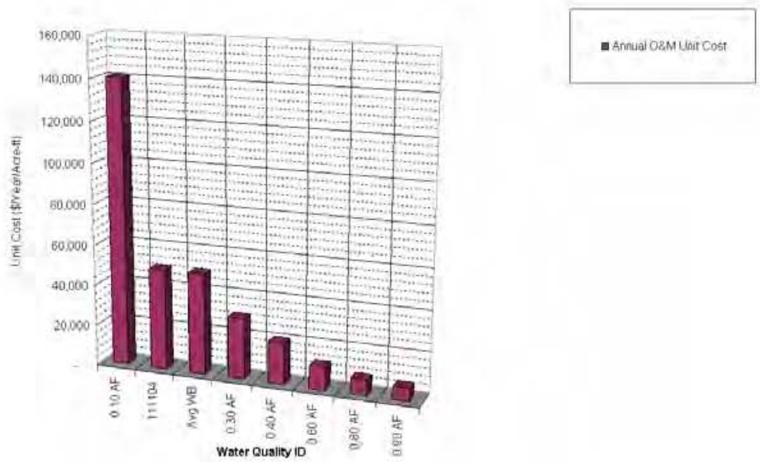
For the 10 water quality design volumes in the table, the Annual O&M Unit Costs ranged from $2,124 to $49,761 per acre-ft, as shown in Graph 10-3. The graph shows that unit cost decreases as design volume increases.

Graph 10-4 represents the Projected Annual O&M Cost data from Table 10-B in ascending order by water quality design volume. This graph shows the decrease in the total projected O&M cost of a WB device as the water quality design volume increases. This is a trend that was unexpected and may not be realized in the future.

TABLE 10-A. ANNUAL O&M UNIT COSTS - WBs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/Acre-ft)
Wet Basins														
0.10 AF										14,053			0.10	140,533
111104	WB	I-5/La Costa (east)	4,210	628	6,167	1,552	-	361	8,708	10,450	4.20	2.23	0.21	49,760
Avg WB										10,450			0.21	49,762
0.30 AF										9,063			0.30	30,209
0.40 AF										8,104			0.40	20,412
0.60 AF										6,872			0.60	11,453
0.80 AF										6,126			0.80	7,657
0.90 AF										5,845			0.90	6,494
	EDB Curve Adjustment Factor									1.86				
	Average WB									$ 10,450			0.21	

GRAPH 10-1. Annual O&M Unit Cost - WBs



GRAPH 10-2. Annual O&M Unit Cost Curves - WBs

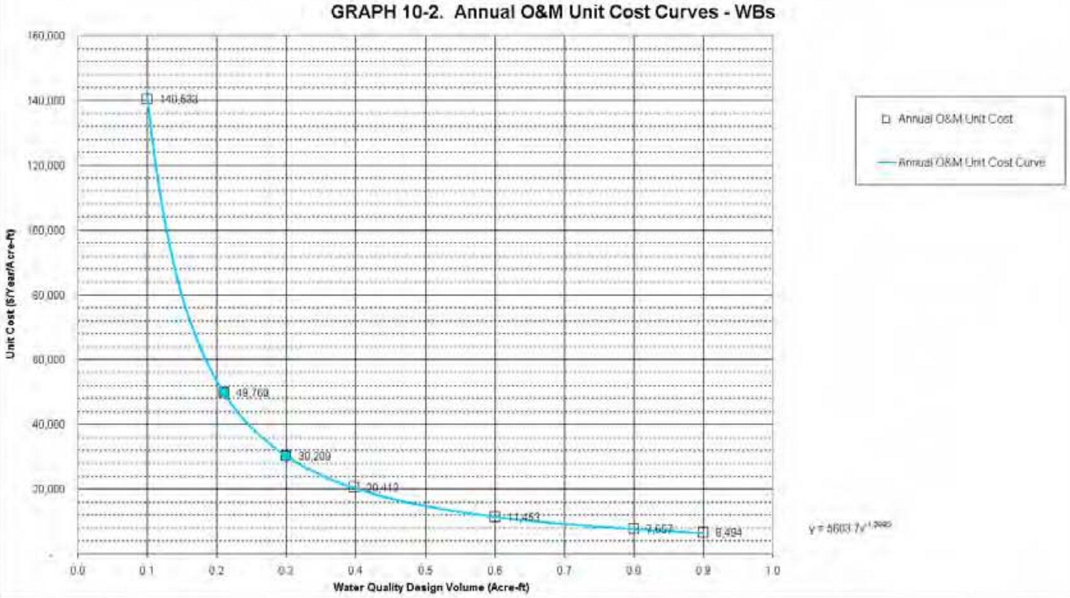
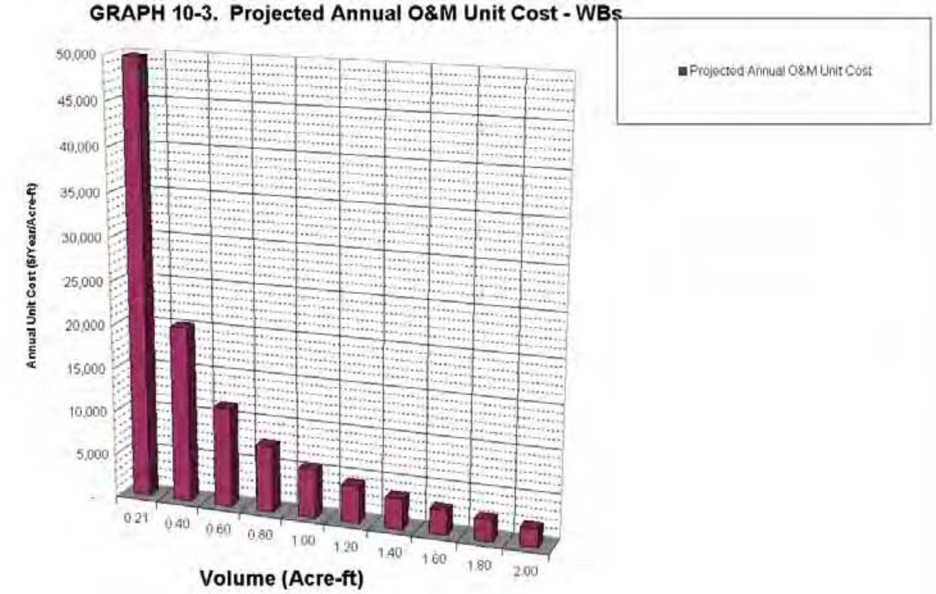


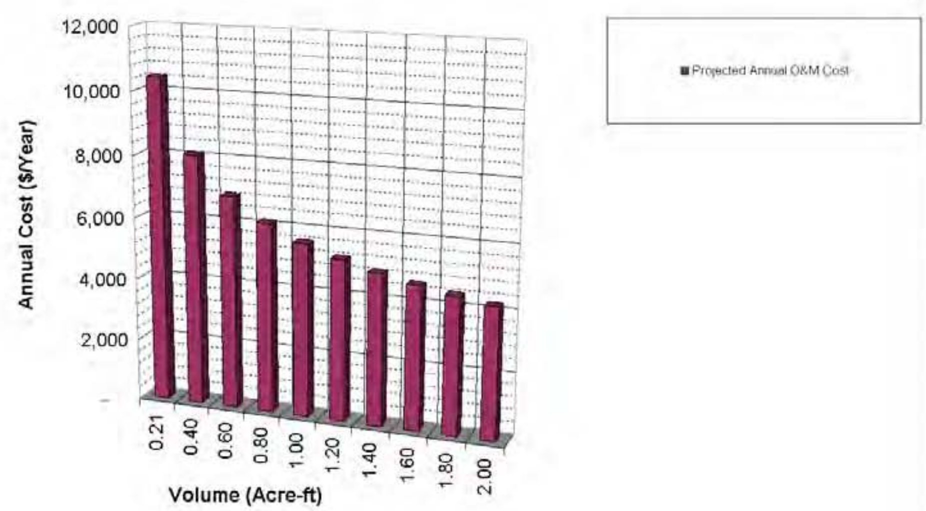
TABLE 10-B. PROJECTED ANNUAL O&M COSTS - WBs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/Acre-ft)
Wet Basin						
111104		10,450	4.20	2.23	0.21	49,761
	Typical Sites with Indicated Water Quality Volume	8,079			0.40	20,198
		6,872			0.60	11,453
		6,126			0.80	7,657
		5,604			1.00	5,604
		5,210			1.20	4,342
		4,899			1.40	3,499
		4,645			1.60	2,903
		4,431			1.80	2,462
		4,249			2.00	2,124

GRAPH 10-3. Projected Annual O&M Unit Cost - WBs



GRAPH 10-4. Projected Annual O&M Cost - WBs



11. Drain Inlet Insert – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Drain Inlet Insert (DII) BMP type. Table 11-A presents the annual O&M unit costs for six DII devices constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the DII are specified by discharge in cfs.

For the six DII installations analyzed from the Pilot Program, the Annual O&M Unit Costs ranged from $6,338 to $101,896 per cfs, as shown in Graph 11-1.

The trend, as shown by the cost curve in Graph 11-2, indicates, the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 11-B shows projected cost data derived using the cost curve equation from Graph 11-2 for 11 different water quality design discharges; the six associated with the Pilot Program installations, and five additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

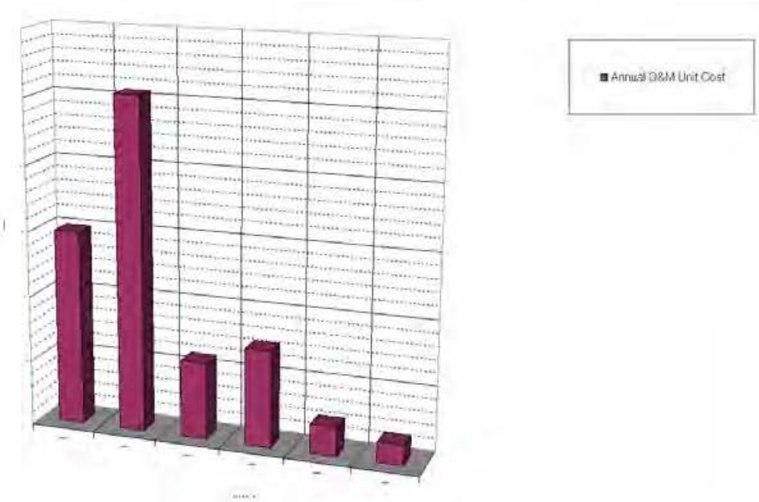
For the 11 water quality design discharges in the table, the Projected Annual O&M Unit Costs ranged from $1,228 to $82,125, as shown in Graph 11-3. The graph shows that unit cost decreases as design volume increases.

Graph 11-4 graphically represents the Projected Annual O&M Cost data from Table 11-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost a DII as the water quality design discharge increases.

TABLE 11-A. ANNUAL O&M UNIT COSTS - DIIs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Drainage Inlet Inserts														
73216a	DII	Foothill Maint. Station	11,032	729	193	519	-	502	1,943	2,332	0.17	0.04	-	59,785
073217a	DII	Las Flores Maint. Station	11,593	591	303	2,368	-	644	3,906	4,687	0.23	0.05	-	101,896
073218a	DII	Rosemead Maint. Station	11,021	633	220	593	-	537	1,983	2,380	0.25	0.10	-	23,706
073217b	DII	Las Flores Maint. Station	11,299	619	811	2,368	-	657	4,455	5,346	0.78	0.18	-	29,700
73216b	DII	Foothill Maint. Station	11,371	701	869	519	-	555	2,644	3,173	1.58	0.35	-	9,065
073218b	DII	Rosemead Maint. Station	11,006	660	784	593	-	551	2,588	3,106	1.20	0.49	-	6,338

GRAPH 11-1. Annual O&M Unit Cost - DIIs



GRAPH 11-2. Annual O&M Unit Cost Curve - DIIs

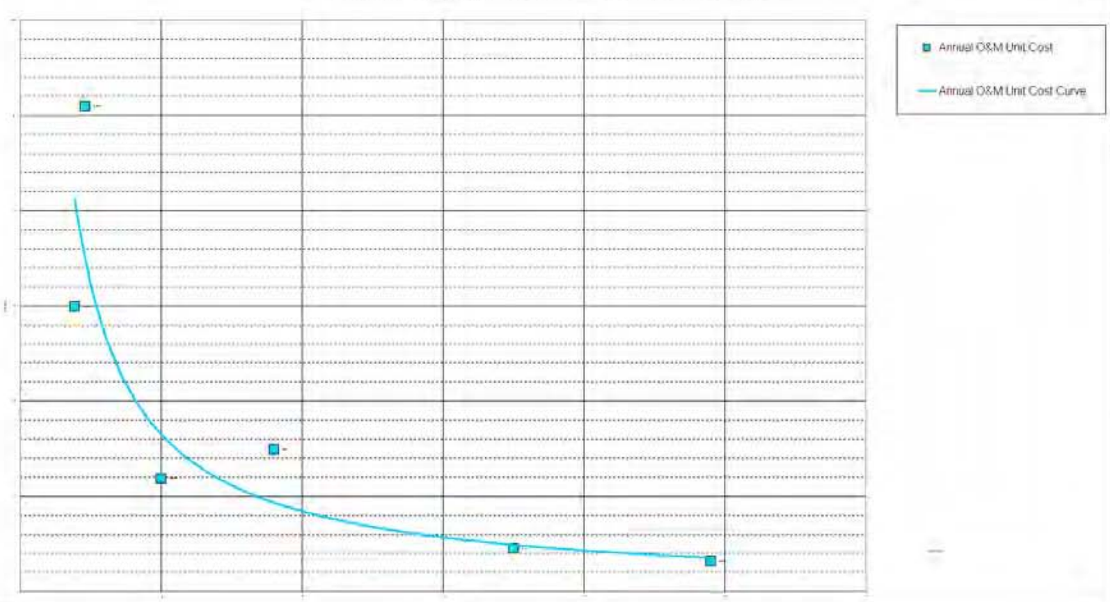
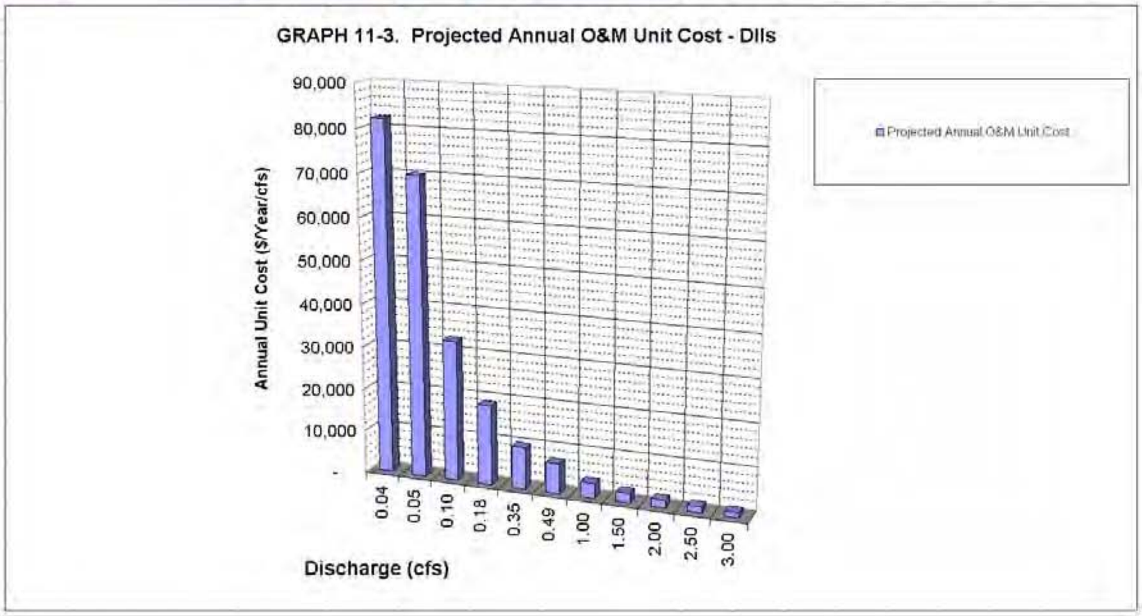
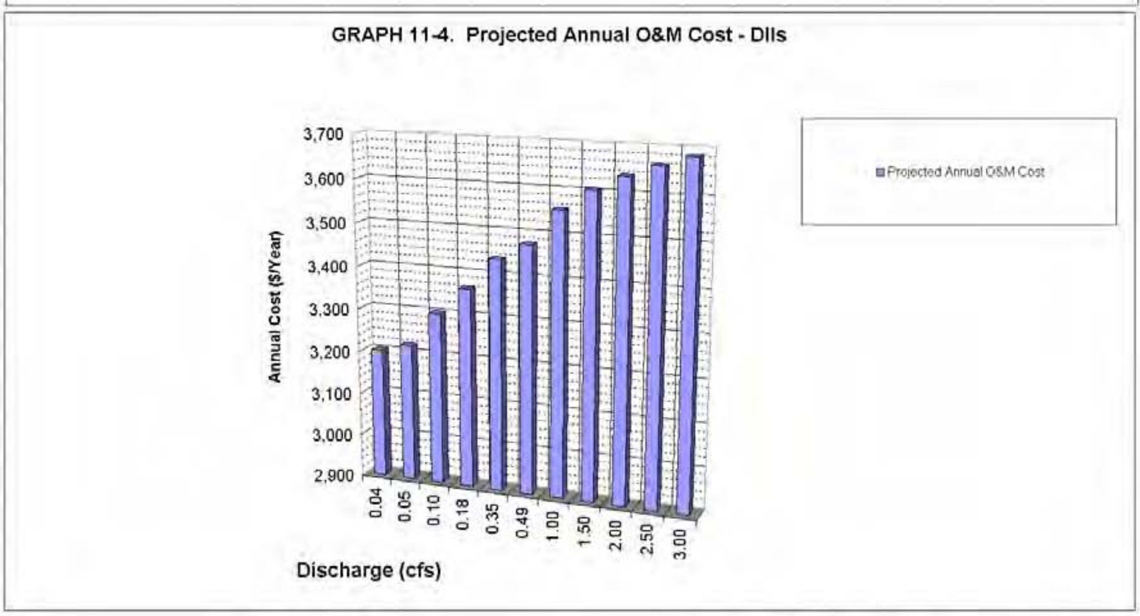


TABLE 11-B. PROJECTED ANNUAL O&M COSTS - DIIs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Drain Inlet Inserts						
73216a	Typical Sites with Indicated Water Quality Discharge	3,203	0.17	0.04	-	82,125
073217a		3,220	0.23	0.05	-	70,000
073218a		3,302	0.25	0.10	-	33,018
073217b		3,365	0.78	0.18	-	18,695
73216b		3,438	1.58	0.35	-	9,823
073218b		3,476	1.20	0.49	-	7,093
		3,557		1.00	-	3,557
		3,604		1.50	-	2,402
		3,637		2.00	-	1,819
		3,664		2.50	-	1,465
		3,685		3.00	-	1,228





12. Oil/Water Separator – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Oil/Water Separator (OWS) BMP type. Table 12-A presents the annual O&M unit costs for the OWS devices constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the OWS are specified by discharge in cfs.

Only one OWS was constructed as part of the Pilot Program. For this reason, the data for the OWS was combined with the data for the Continuous Deflection Separator (CDS) to provide additional data to project construction costs for both devices.

For the three OWS installations analyzed from the Pilot Program, the Annual O&M Unit Costs ranged from $3,364 to $8,242 per cfs, as shown in Graph 12-1.

The trend, as shown by the cost curve in Graph 12-2, indicates, the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 12-B shows projected cost data derived using the cost curve equation from Graph 12-2 for seven different water quality design discharges; the one associated with the Pilot Program installation, and six additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

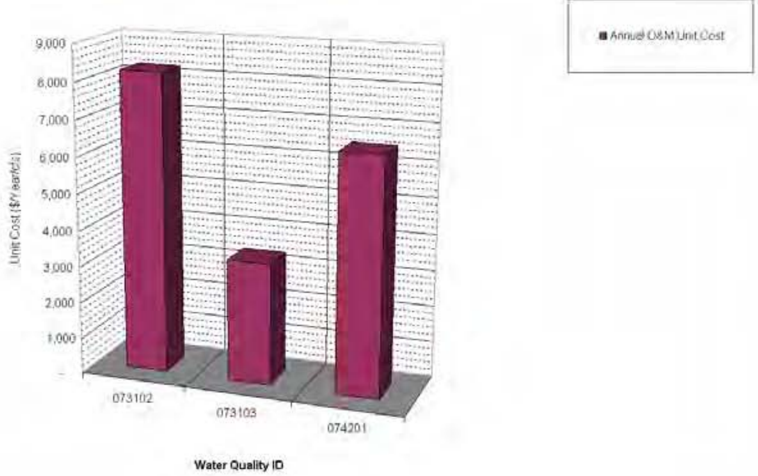
For the seven water quality design discharges in the table, the Projected Annual O&M Unit Costs ranged from $3,869 to $5,739, as shown in Graph 12-3. The graph shows that unit cost decreases as design volume increases.

Graph 12-4 graphically represents the Projected Annual O&M Cost data from Table 12-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost an OWS as the water quality design discharge increases.

TABLE 12-A. ANNUAL O&M UNIT COSTS - OWSs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Oil Water Separators														
073102	CDS	I-210/Orcas Ave	2,343	-	399	1,021	-	297	1,717	2,060	1.09	0.25	-	8,242
073103	CDS	I-210/Fillmore Ave	2,267	-	413	947	-	266	1,626	1,951	1.74	0.58	-	3,364
074201	OWS	Alameda Maint. Station	6,412	450	169	3,704	-	1,432	5,755	6,906	0.75	1.06	0.05	6,515

GRAPH 12-1. Annual O&M Unit Cost - OWSs



GRAPH 12-2. Annual O&M Unit Cost Curve - OWSs

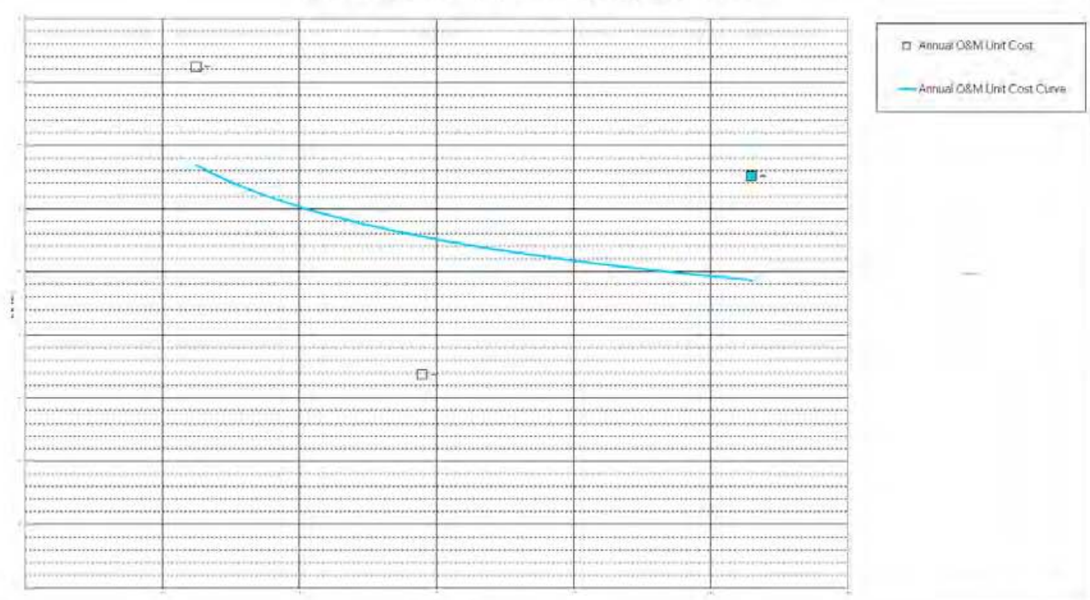
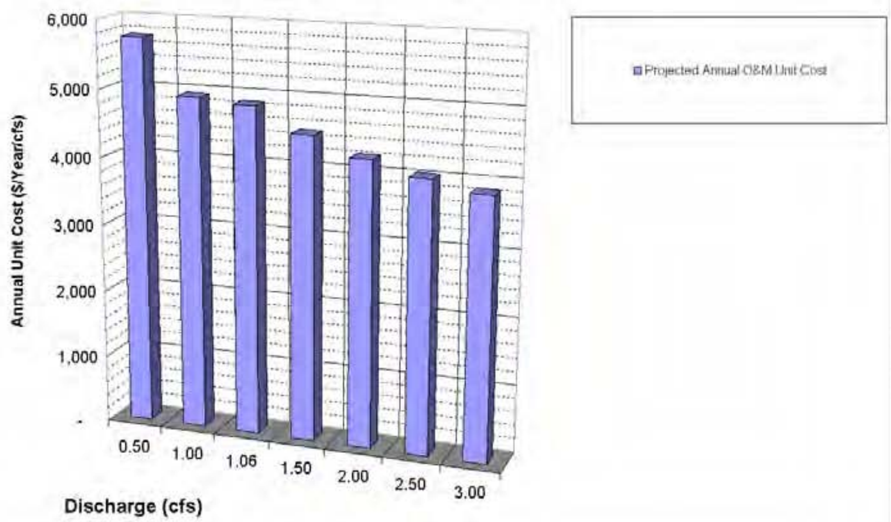


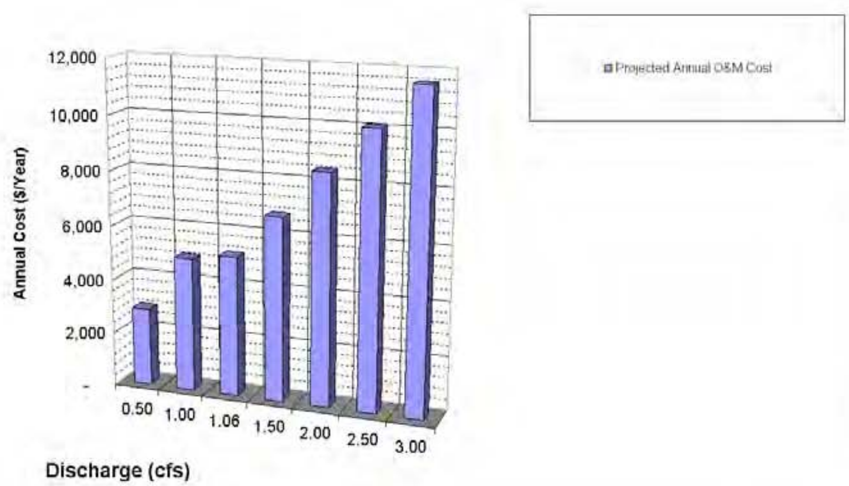
TABLE 12-B. PROJECTED ANNUAL O&M COSTS - OWSs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Oil Water Separators						
		2,870		0.50	-	5,739
		4,927		1.00	-	4,927
074201	Typical Sites with Indicated Water Quality Discharge	5,156	0.75	1.06	0.05	4,865
		6,760		1.50	-	4,507
		8,460		2.00	-	4,230
		10,068		2.50	-	4,027
		11,607		3.00	-	3,869

GRAPH 12-3. Projected Annual O&M Unit Cost - OWSs



GRAPH 12-4. Projected Annual O&M Cost - OWSs



13. Continuous Deflection Separator – Projected Annual O&M Cost Analysis

This section projects annual O&M costs for the Continuous Deflection Separator (CDS) BMP type. Table 13-A presents the annual O&M unit costs for the CDS devices constructed as part of the Pilot Program, listed in ascending order by water quality design size. Water quality design units for the CDS are specified by discharge in cfs.

Only two CDS devices were constructed as part of the Pilot Program. For this reason, the data for the CDS was combined with the data for the OWS to provide additional data to project construction costs for both devices.

For the three CDS installations analyzed from the Pilot Program, the Annual O&M Unit Costs ranged from $3,364 to $8,242 per cfs, as shown in Graph 13-1.

The trend, as shown by the cost curve in Graph 13-2, indicates, the annual O&M unit costs are projected to decrease as water quality design discharge increases.

Table 13-B shows projected cost data derived using the cost curve equation from Graph 13-2 for eight different water quality design discharges; the two associated with the Pilot Program installations, and six additional discharges representing a typical range of values. The data are listed in ascending order by water quality design discharge.

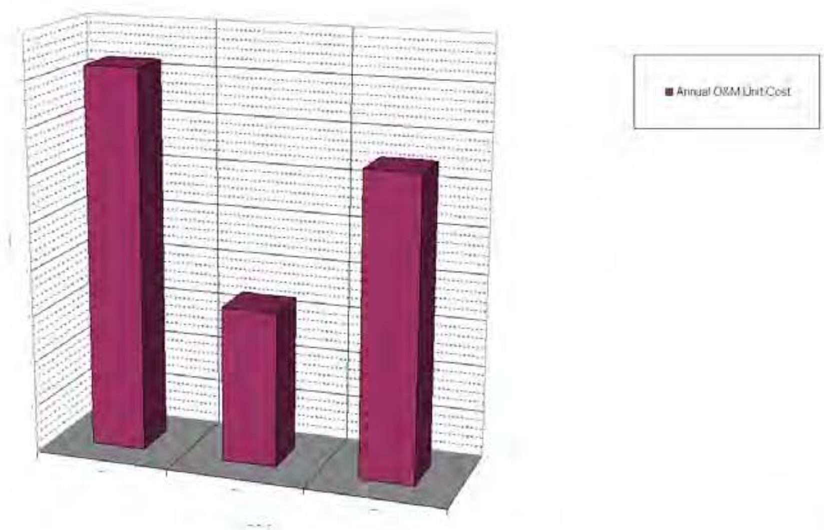
For the eight water quality design discharges in the table, the Projected Annual O&M Unit Costs ranged from $3,869 to $6,685, as shown in Graph 13-3. The graph shows that unit cost decreases as design volume increases.

Graph 13-4 graphically represents the Projected Annual O&M Cost data from Table 13-B in ascending order by water quality design discharge. This graph shows the increase in the projected annual O&M cost a CDS as the water quality design discharge increases.

TABLE 13-A. ANNUAL O&M UNIT COSTS - CDSs

WQ ID No.	BMP Type	Site Location	Administration Cost ($/10 mo)	Operation Cost ($/10 mo)	Maintenance Cost ($/10 mo)	Vector Control Cost ($/10 mo)	Equipment Cost ($/10 mo)	Direct Cost ($/10 mo)	Total O&M Cost (less Admin) ($/10 mo)	Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Annual O&M Unit Cost ($/Year/cfs)
Contiuous Deflection Separators														
073102	CDS	I-210/Orcas Ave	2,343	-	399	1,021	-	297	1,717	2,060	1.09	0.25	-	8,242
073103	CDS	I-210/Fillmore Ave	2,267	-	413	947	-	266	1,626	1,951	1.74	0.58	-	3,364
074201	OWS	Alameda Maint. Station	6,412	450	169	3,704	-	1,432	5,755	6,906	0.75	1.06	0.05	6,515

GRAPH 13-1. Annual O&M Unit Cost - CDSs



GRAPH 13-2. Annual O&M Unit Cost Curve - CDSs

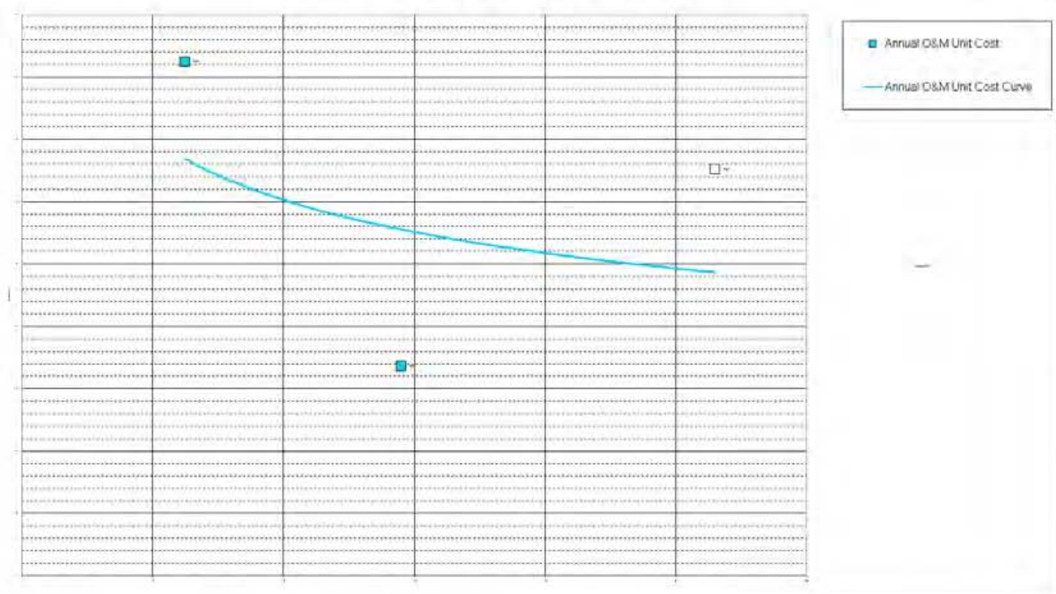
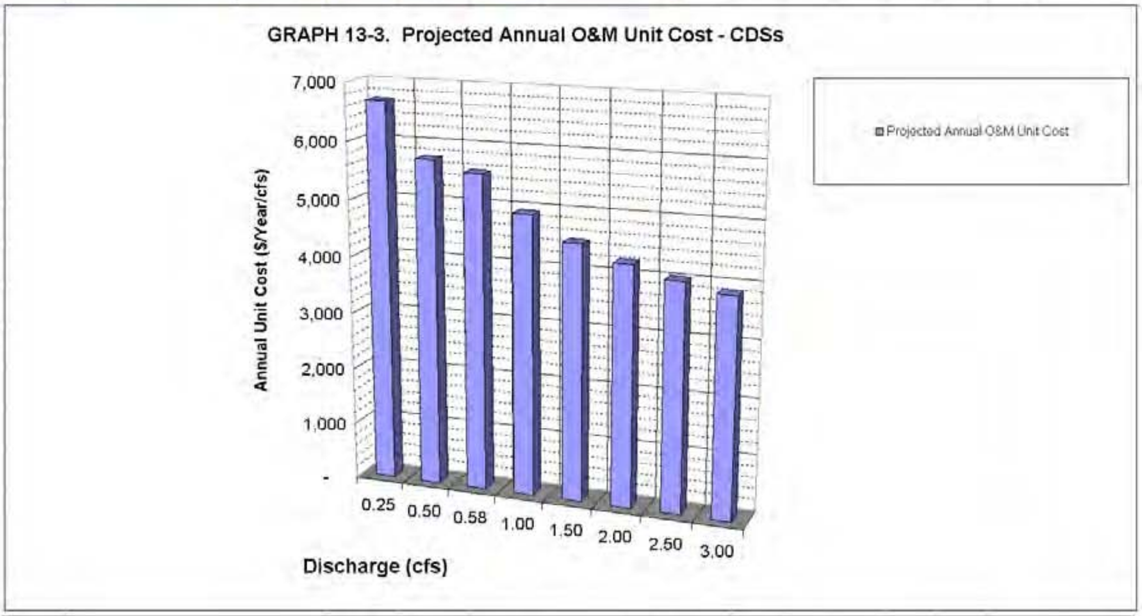
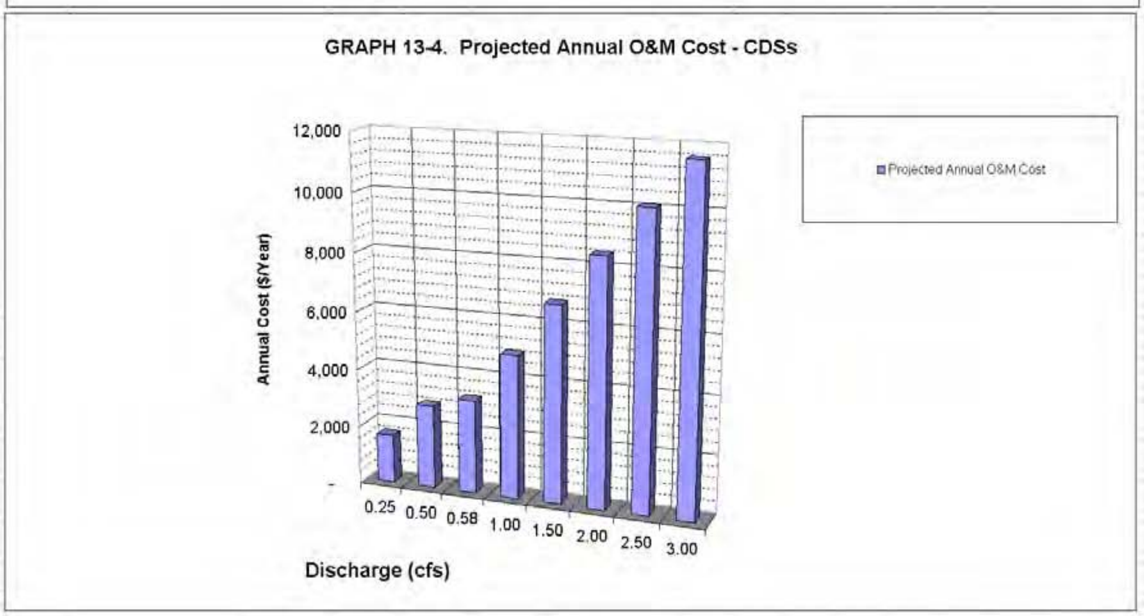


TABLE 13-B. PROJECTED ANNUAL O&M COSTS - CDSs

WQ ID No.	Site Location	Projected Annual O&M Cost ($/Year)	Tributary Drainage Area (Acres)	Water Quality Design Discharge (cfs)	Water Quality Design Volume (Acre-ft)	Projected Annual O&M Unit Cost ($/Year/cfs)
Continuous Deflection Separators						
073102	Typical Sites with Indicated Water Quality Discharge	1,671	1.09	0.25	-	6,685
		2,870		0.50	-	5,739
073103		3,222	1.74	0.58	-	5,555
		4,927		1.00	-	4,927
		6,760		1.50	-	4,507
		8,460		2.00	-	4,230
		10,068		2.50	-	4,027
		11,607		3.00	-	3,869





F. Section II Conclusions

In Section II, BMP Pilot Program Analysis, the third party team thoroughly examined the individual BMP installations constructed as part of the Caltrans BMP Retrofit Pilot Program. The team categorized and analyzed the cost data and identified trends. In their analysis, the team considered the applicable questions provided by the oversight committee as guidance.

The team has identified and categorized all of the costs associated with the construction of the BMP installations in the Pilot Program to arrive at a basis to perform cost comparisons. This basis is arrived at by first eliminating the costs influenced by the constraints of the Pilot Program and non-BMP essential costs. The remaining cost items, identified as the Adjusted Construction Costs, include the cost to construct the BMP device and the associated site-specific costs.

To accurately compare the adjusted construction costs of the BMP devices of the Caltrans Pilot Program to construction costs from other agencies, a comparable unit is needed. From study of the data, the most logical unit identified is the "water quality design unit" (discharge rate or volume, depending on the BMP type). To obtain the construction cost per water quality design unit, the adjusted construction cost is divided by the unit volume or unit discharge rate.

Analyses of the construction cost data generated by the Pilot Program have identified some cost-reducing factors. The trends identified are based on limited data and corroboration with data from other agencies is important to validate these trends.

- For all BMP types, the general cost-reducing trend is to maximize the water quality design unit. That is, in general, the cost per unit of water treated decreases as the water quality design increases.
- Constructing the BMP devices as part of a larger construction project, redevelopment or new construction, is less costly than constructing a BMP alone as a retrofit. Retrofit costs for each BMP installation have been identified, and likely can be deleted in such a case, but these costs only account for some of the cost savings. Most likely, any major cost reductions will be identified by other agencies that have constructed BMP devices as part of a larger construction project.
- For most BMP types, the general cost-reducing trend for O&M costs is similar to the construction cost which is to maximize the water quality design unit

In the following sections, BMP device construction and O&M costs and trends identified by other agencies are detailed and compared to the Caltrans Pilot Program construction and O&M costs.

III. BMP CAPITAL COST EXPERIENCE OF OTHER AGENCIES

This section documents retrofit BMP costs for entities other than Caltrans. To the extent that other agency costs are different, this section also presents reasons for the differences. Cost data was obtained from several state transportation departments and other public entities with significant experience planning, designing, and constructing structural water quality controls. Information was also obtained from vendors of the four proprietary BMP systems used in the Caltrans pilot program.

State transportation departments and other public entities were interviewed to create a short list of stormwater management entities with significant experience implementing water quality controls. Each of the contacts was asked to offer referrals to other states in their region that might offer useful BMP expertise. All states bordering California (Arizona, Nevada and Oregon) were included.

Questions were asked to solicit basin information regarding:

- BMP costs;
- The numbers of years of experience using structural BMPs;
- Types of areas from which storm runoff is treated (roadways, other land uses, etc.);
- Whether retrofit BMPs are used and reasons if they are not used;
- Cost-effective BMP technologies; and
- Strategies used to limit costs to implement BMPs.

Entities with significant and/or relevant BMP experience were identified based upon several factors. These factors included the number of years of experience with storm water treatment, the number and range of BMPs technologies deployed, implementation within a urban setting, and published papers or design standards. Based on these criteria, the following entities have significant experience relevant to California highway storm water retrofit projects:

1. City of Austin, Texas
2. City of Portland, Oregon
3. Delaware DOT
4. Florida DOT
5. King County, Washington
6. Maryland SHA
7. Oregon DOT
8. Prince George's County, Maryland
9. Snohomish County, Washington
10. Virginia DOT
11. Washington State DOT

These agencies, except Florida DOT are located either in one of two geographic clusters: the Mid-Atlantic area or the Pacific Northwest area, or near the home offices of Glenrose

Engineering. Trips were therefore made by Glenrose Engineering and Holmes and Narver, Inc. staff to each of these agencies to collect data, interview staff, and field visit representative BMPs.

A. General Description of BMP Programs of Other Entities and Caltrans

1. Background Information on Other Entities

Summary information regarding storm water management programs of state transportation departments and other entities is summarized in Table 3-1. This table provides information on the similarities and/or differences between other transportation agencies and Caltrans. States with the oldest water quality protection measures using or requiring structural BMPs for their highways are Maryland, Florida, and Illinois, each with programs that are 20 to 30 years old. More commonly, state programs began in the early 1990s. California's start date in 1997, is one of the most recent.

There is also a wide range in the number of constructed BMP structures by each entity, from a few dozen to thousands. Program directors typically know only approximately the number of BMPs constructed for their roadway systems. California, with 34 BMPs is near the low end of the number of practices constructed.

Most state transportation departments interviewed had some experience with BMPs. Most require BMPs for new roadway construction, contingent for some upon the sensitivity of runoff receiving waters. BMPs are also generally required for reconstruction that either requires a permit or increases impervious cover. About one-half of the states include some program to provide BMPs for existing highway system infrastructure. Very few states, however, have constructed stand-alone retrofits solely to treat runoff from existing infrastructure and not in conjunction with other (e.g., roadway) construction activities. To the extent that existing, previously untreated areas were treated with new BMPs, it was largely as part of a redevelopment (e.g., a lane addition or interchange upgrade) or new construction program. Stormwater managers report significantly higher construction costs for stand-alone retrofit BMPs. Transportation departments use a variety of BMP design and contracting procedures to treat runoff from existing roadways and infrastructure without building stand-alone retrofits. These approaches enhance BMP site selection and technology flexibility, and take advantage of economies of scale in facility size and construction activities. These methods are discussed in III.B. below.

State transportation department managers report the use of a wide variety of BMP technologies. Wet and dry storm ponds and vegetated swales are widely used. Some of the technologies used by other agencies were not represented in the Caltrans pilot program. These included Vortechs™ separators, bioretention systems, pervious pavers, wet vaults, trapping catch basins, and streambank restoration. Some of these technologies are similar to those used in the pilot retrofit study. Others were considered for the Caltrans pilot program but were not implemented due to concerns about their lack of effectiveness and difficulty and cost to install. Some managers report a desire to avoid complicated BMP technologies, proprietary systems, or systems requiring pumps because of the associated operations and maintenance expense.

Most state departments have limited information readily available regarding BMP construction costs. Table 3-2 presents a summary of the BMP construction cost information obtained for the this report. All cost data have been adjusted using national construction factors to equivalent Los Angeles region, 1999 costs. Except for inlet filters, which cost only a couple thousand dollars, reported BMP costs range from $11,000 for construction in rural areas to several millions of dollars for construction in ultra-urban areas with expensive ROW acquisition costs.

Table 3-2. Comparative BMP Data for Individual Sites

Entity*	BMP Type	Drainage Area (acres)	Water Quality Volume (ft^3)**	Adjusted Total Cost***	Adjusted Total Cost per Acre Treated
1. City of Austin	Wetland	252.00	-	$ 434,310	$ 1,723
2. City of Austin	Wet Pond	173.00	-	$ 865,656	$ 5,004
3. City of Austin	Austin Sand Filter	66.00	-	$ 410,701	$ 6,223
4. City of Austin	Wet Pond	78.00	-	$ 493,151	$ 6,322
5. City of Austin	ED Pond	130.00	-	$ 1,282,221	$ 9,863
6. City of Austin	Wet Pond	57.00	-	$ 412,329	$ 7,234
7. City of Austin	Austin Sand Filter	32.00	-	$ 115,553	$ 3,611
8. City of Austin	Wet Pond	907.00	-	$ 2,221,441	$ 2,449
9. City of Austin	Wet Pond	109.00	-	$ 335,748	$ 3,080
10. City of Austin	Wet Pond	72.00	-	$ 1,128,870	$ 15,679
11. City of Austin	Wet Pond	462.00	-	$ 912,362	$ 1,975
12. Florida DEP	Wetland	2,200.00	7,570,728	$ 5,589,195	$ 2,541
13. Florida DEP	Wetland	527.00	2,874,960	$ 834,558	$ 1,584
14. Florida DEP	Wetland	121.00	-	$ 1,302,685	$ 10,766
15. Florida DEP	OWS	49.00	-	$ 191,247	$ 3,903
16. Florida DEP	Wetland	9.24	-	$ 127,766	$ 13,827
17. Florida DEP	Wet Pond	390.00	-	$ 1,125,538	$ 2,886
18. Florida DEP	Infiltration Trench	49.00	30,700	$ 827,808	$ 16,894
19. Florida DEP	CDS	40.00	-	$ 72,416	$ 1,810
20. Florida DEP	OWS	5.00	-	$ 369,958	$ 73,992
21. King County	Wetland	6.30	-	$ 74,540	$ 11,832
22. King County	Wetland	3.37	6,900	$ 96,776	$ 28,717
23. King County	Wetland	8.34	-	$ 90,331	$ 10,831
24. CWP	Wet Pond	22.10	101,930	$ 56,155	$ 2,541
25. CWP	Wet Pond	36.00	130,680	$ 57,067	$ 1,585
26. CWP	Wet Pond	2.80	22,651	$ 37,206	$ 13,288
27. CWP	Wet Pond	82.10	22,433	$ 101,785	$ 1,240
28. CWP	Wet Pond	12.30	122,804	$ 264,197	$ 21,479
29. CWP	Wet Pond	11.70	1,019,304	$ 498,808	$ 42,633
30. CWP	Wet Pond	12.80	91,476	$ 215,941	$ 16,870
31. CWP	Wet Pond	13.90	100,188	$ 390,608	$ 28,101
32. CWP	Wet Pond	15.30	113,256	$ 282,133	$ 18,440
33. CWP	ED Pond	3.20	28,314	$ 19,091	$ 5,966
34. CWP	ED Pond	380.80	1,434,431	$ 382,556	$ 1,005
35. CWP	ED Pond	10.90	36,590	$ 40,752	$ 3,739
36. CWP	ED Pond	3.70	22,651	$ 29,319	$ 7,924
37. CWP	ED Pond	19.50	100,188	$ 83,875	$ 4,301
38. CWP	ED Pond	44.30	187,308	$ 165,652	$ 3,739
39. CWP	ED Pond	4.50	9,200	$ 16,464	$ 3,659
40. CWP	ED Pond	77.90	36,435	$ 34,882	$ 448
41. CWP	ED Pond	35.00	16,155	$ 12,558	$ 359
42. CWP	ED Pond	201.00	483,516	$ 314,033	$ 1,562

Table 3-2. Comparative BMP Data for Individual Sites (continued)

	BMP Type	Drainage Area (acres)	Water Quality Volume (ft³)**	Adjusted Total Cost***	Total Cost per Acre Treated
43. CWP	ED Pond	16.50	222,156	$ 206,571	$ 12,519
44. CWP	ED Pond	3.10	5,663	$ 6,813	$ 2,198
45. CWP	ED Pond	2.30	7,841	$ 6,813	$ 2,962
46. CWP	ED Pond	59.10	655,523	$ 210,793	$ 3,567
47. CWP	ED Pond	229.90	3,571,920	$ 1,041,912	$ 4,532
48. CWP	ED Pond	25.00	222,447	$ 78,536	$ 3,141
49. CWP	ED Pond	4.30	11,258	$ 17,507	$ 4,071
50. CWP	ED Pond	3.10	10,600	$ 13,626	$ 4,396
51. CWP	Wetland	9.30	38,768	$ 36,135	$ 3,886
52. CWP	Wetland	798.30	5,985,144	$ 1,204,859	$ 1,509
53. CWP	Wetland	29.10	102,366	$ 103,114	$ 3,543
54. CWP	Wetland	26.60	148,104	$ 20,178	$ 759
55. CWP	Wetland	611.30	1,032,372	$ 126,182	$ 206
56. CWP	Wetland	95.00	326,700	$ 181,014	$ 1,905
57. CWP	Wetland	155.00	622,908	$ 568,371	$ 3,667
58. CWP	Wetland	47.40	322,344	$ 224,179	$ 4,730
59. CWP	Wetland	63.10	426,888	$ 222,575	$ 3,527
60. CWP	Wetland	194.00	1,655,280	$ 354,636	$ 1,828
61. CWP	Wetland	73.00	69,696	$ 108,029	$ 1,480
62. CWP	Wetland	10.40	156,070	$ 72,383	$ 6,960
63. CWP	Wetland	13.10	77,351	$ 30,125	$ 2,300
64. CWP	Swale	0.87	6,778	$ 18,089	$ 20,792
65. CWP	Swale	80.00	-	$ 3,561	$ 45
66. CWP	Swale	5.00	-	$ 18,932	$ 3,786
67. CWP	Compost Filter	4.40	11,780	$ 23,700	$ 5,386
68. CWP	Compost Filter	11.70	9,148	$ 40,769	$ 3,485
69. CWP	Compost Filter	4.70	2,200	$ 24,604	$ 5,235
70. CWP	Compost Filter	1.10	-	$ 11,651	$ 10,592
71. CWP	Compost Filter	1.10	-	$ 10,299	$ 9,363
72. CWP	Compost Filter	1.70	-	$ 29,858	$ 17,563
73. CWP	Compost Filter	0.50	-	$ 11,687	$ 23,375
74. CWP	Compost Filter	2.70	-	$ 28,873	$ 10,694
75. CWP	Compost Filter	1.00	-	$ 10,016	$ 10,016
76. CWP	Compost Filter	3.40	-	$ 35,863	$ 10,548
77. CWP	Compost Filter	73.00	-	$ 196,155	$ 2,687
78. CWP	Austin Sand Filter	2.00	478	$ 58,629	$ 29,315
79. CWP	Austin Sand Filter	13.60	4,008	$ 18,970	$ 1,395
80. CWP	Austin Sand Filter	0.50	7,363	$ 31,798	$ 63,597
81. CWP	Austin Sand Filter	2.10	7,224	$ 31,431	$ 14,967
82. CWP	Austin Sand Filter	2.90	1,617	$ 22,825	$ 7,871
83. CWP	Delaware Sand Filter	0.62	103	$ 19,111	$ 30,824
84. CWP	Delaware Sand Filter	1.30	9,313	$ 179,421	$ 138,016
85. CWP	Delaware Sand Filter	1.30	11,752	$ 191,893	$ 147,610
86. CWP	Delaware Sand Filter	1.60	2,933	$ 69,524	$ 43,452

Table 3-2. Comparative BMP Data for Individual Sites (continued)

Entity*	BMP Type	Drainage Area (acres)	Water Quality Volume (ft^3)**	Adjusted Total Cost***	Adjusted Total Cost per Acre Treated
87. CWP	Infiltration Trench	0.20	1,900	$ 7,571	$ 37,854
88. CWP	Infiltration Trench	0.54	1,346	$ 6,766	$ 12,529
89. CWP	Infiltration Trench	0.92	446	$ 10,084	$ 10,961
90. CWP	Infiltration Trench	0.59	706	$ 29,589	$ 50,151
91. CWP	Infiltration Trench	0.62	1,880	$ 5,362	$ 8,649
92. MD SHA	ED Pond	15.41	-	$ 155,706	$ 10,104
93. MD SHA	ED Pond	145.31	253,200	$ 267,680	$ 1,842
94. MD SHA	ED Pond	6.60	3,000	$ 39,388	$ 5,968
95. MD SHA	Austin Sand Filter	2.06	3,740	$ 38,201	$ 18,544
96. MD SHA	Bioretention Filter	4.24	-	$ 82,206	$ 19,388
97. MD SHA	Wetland	24.18	-	$ 179,661	$ 7,430
98. MD SHA	Infiltration Trench	6.80	12,342	$ 53,192	$ 7,822
99. MD SHA	Wet Pond	143.00	171,000	$ 235,955	$ 1,650
100. MD SHA	Wetland	2.90	15,000	$ 22,969	$ 7,920
101. MD SHA	Wetland	1.20	17,000	$ 14,507	$ 12,089
102. MD SHA	Wet Pond	37.40	59,000	$ 275,480	$ 7,366
103. MD SHA	Bioretention Filter	2.30	35,000	$ 167,716	$ 72,920
104. MD SHA	Wet Pond	15.62	51,400	$ 106,384	$ 6,811
105. MD SHA	Wet Pond	13.70	30,000	$ 84,623	$ 6,177
106. MD SHA	Wet Pond	11.85	23,100	$ 73,743	$ 6,223
107. MD SHA	Infiltration Trench	7.71	15,900	$ 41,921	$ 5,437
108. ODOT	ED Pond	2.90	-	$ 71,540	$ 24,669
109. ODOT	Swale	1.17	-	$ 41,736	$ 35,672
110. Olympia	Wetland	500.00	-	$ 2,161,693	$ 4,323
111. Santa Monica	CDS	90.00	-	$ 312,103	$ 3,468
112. Snohomish County	StormFilter	0.22	50	$ 18,947	$ 86,121
113. TxDOT	Austin Sand Filter	6.25	14,088	$ 301,293	$ 48,207
114. TxDOT	Austin Sand Filter	6.01	15,585	$ 301,293	$ 50,132
115. TxDOT	Austin Sand Filter	9.80	26,740	$ 1,281,751	$ 130,791
116. TxDOT	Austin Sand Filter	96.25	193,362	$ 1,232,608	$ 12,806
117. TxDOT	Austin Sand Filter	86.42	163,300	$ 3,214,831	$ 37,200
118. TxDOT	Austin Sand Filter	70.82	-	$ 1,763,513	$ 24,901
119. TxDOT	Austin Sand Filter	241.05	-	$ 4,007,301	$ 16,624
120. TxDOT	Wet Pond	64.00	-	$ 718,027	$ 11,219
121. Wisconsin	MCTT	0.25	-	$ 87,724	$ 350,896
122. Wisconsin	MCTT	2.50	-	$ 125,320	$ 50,128

Table 3-2. Comparative BMP Data for Individual Sites (continued)

City of Austin	City of Austin Watershed Protection Department
Florida DEP	Florida Department of Environmental Protection
King County	King County, Washington
CWP	Center for Watershed Protection BMP Cost Database (Brown & Schueler, 1997)
MD SHA	Maryland State Highway Administration
ODOT	Oregon Department of Transportation
Olympia	City of Olympia, Washington
Santa Monica	City of Santa Monica, California
Snohomish County	Snohomish County, Washington
TxDOT	Texas Department of Transportation
Wisconsin	Wisconsin MCTT information (Pitt et al., 1999)

** Blank (-) entries indicate incomplete data or facilities which do not have water quality volumes (e.g., are sized using flow, not volume).

*** All costs adjusted to Los Angeles region, 1999, using Means® localization factors and Engineering News Record (ENR) Construction Cost Index.

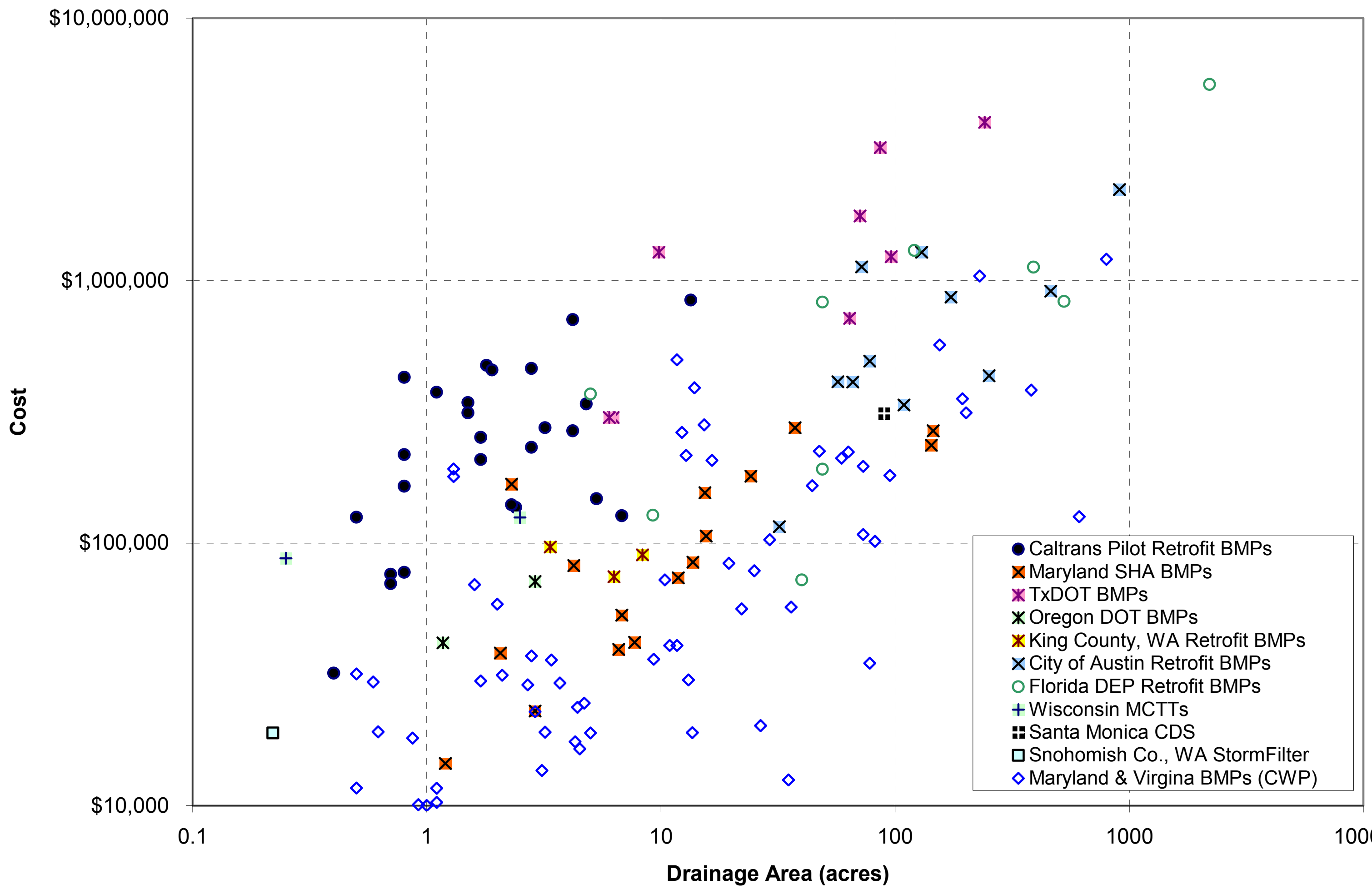
2. Comparison in Terms of Dollars per Unit Treated

Figure 3-1 shows a comparison of costs between Caltrans pilot program BMPs and data obtained for this study from the following entities:

- Maryland State Highway Administration (SHA)
- Texas Department of Transportation (TxDOT)
- City of Austin, Texas
- King County, Washington
- Wisconsin MCTTs;
- Florida Department of Environmental Quality;
- Maryland and Virginia BMP data collected by the Center for Watershed Protection; and
- City of Santa Monica, California

Caltrans BMPs are generally higher in cost than those of other entities for the same size drainage area. Some of the comparison BMP costs were taken from Brown and Schueler (1997) in a report done by the Center for Watershed Protection. This report's findings have subsequently served as the basis for the cost conclusions for BMPs for several subsequent national publications, including US EPA's *Preliminary Data Summary of Urban Storm Water Best Management Practice* (August 1999).

Figure 3-1. Drainage Area vs. BMP Total Construction Cost for Caltrans and Other Entities (Log Scale)



Note: Costs for most of the above BMPs are Total Project Costs (i.e., engineering and other possible costs are included with construction costs). Costs for Caltrans BMPs include construction costs only.

B. Construction Cost Factors

The following sections describe planning, administration, and design factors that influence the cost of a BMP construction program, based on the experience of other storm water management entities.

1. Program Administration and Planning

Effective administrative structures and planning systems anticipate and capitalize on opportunities for cost-effective BMPs implementation.

a) Staff Implementation Experience with BMPs

Experience is critical to developing a successful program and controlling costs. BMP implementation during the first years of a program can be expensive and difficult because of unfamiliar technologies and lack of experience. Agencies report internal conflicts, questions regarding the usefulness of water quality controls and opposition to their implementation during the initiation of a water quality management program. Managers consistently reported that after at least five years program managers, technical staff, engineers, consultants, and contractors were familiar and experienced in BMP planning, design, construction, and operation.
Managers reported an initial tendency to manage water quality requirements as a separate task added to existing project schedules. With this separate management structure, BMPs were not considered in the early stages of projects when cost-relevant decisions like land use and drainage infrastructure design are made. With experience, departments learned to integrate BMP designs into the initial roadway design process and reduce costs.

For each type of BMP technology, managers report that the design and construction process was also initially slower and more expensive. Lower costs were achieved when engineers, contractors, and project managers gained experience in their design and construction. Most departments found that experience over several years was needed to determine which BMP technologies were most cost-effective. Designs, plans, and materials standardization (including custom components designed by local manufacturers) lowered costs and increased project predictability over time. Most departments still consider themselves to be in the process of improving approaches to BMP implementation, experimenting with and making modifications to existing and new technologies. Staff experience was widely regarded as one of the most important factors in lowering costs.

b) Administrative Structure

The number of persons employed by state transportation departments for storm water quality management ranges widely. Of the departments interviewed, Maryland has the largest staff, 50. Most other departments had much smaller staff sizes ranging from zero full time staff to four or five people. Most have few people with full time responsibility for water quality engineering, and duties are divided among engineers or staff with other responsibilities.

Maryland State Highway Administration, with the largest staff, had the most comprehensive long-range planning program. Washington State DOT, conversely, employed a much smaller staff and outside consultants to develop a comprehensive long-range planning program. Most state transportation department storm water managers felt that they had too few staff to get the job done as effectively as they would have wished.

The ability to dedicate an adequate number of staff to up-front planning can greatly affect project costs. Bill Leif of Snohomish County, Washington, summarized the cost-saving benefits of having staff perform up-front planning for roadway BMPs. Planning allows an agency to better take advantage of all possible opportunities, many of which are unforeseen without such efforts.

2. Regional Planning

Faced with the need to provide cost-effective retrofit BMPs, a number of innovative planning strategies have been devised by storm water departments across the US. These strategies include:

- Watershed Master Planning;
- Integrated BMPs;
- BMPs for Redevelopment;
- Regional Deployment and Partnerships;
- Compensatory Treatment; and
- BMP Technology Selection.

These six strategies interrelate and have been effectively used in combination by the storm water departments interviewed. A description of each of these strategies is included below.

a) Watershed Master Planning

Several states, transportation departments, and local communities have begun master planning processes for watershed protection and restoration. The objective of these planning processes is to develop comprehensive ways to improve water quality, address flood control issues, and protect stream channel integrity and aquatic habitat. These plans generally combine both structural BMP retrofits and nonstructural strategies.

One objective of the planning process is to select the most advantageous and cost-effective structural BMPs possible and to integrate these practices directly into larger construction projects. This limits the need for future “stand-alone” retrofits, which are usually more expensive. Planning also provides a basis for integrating projects within a watershed and prioritizing projects within and among watersheds to achieve water quality goals.

(1) City of Austin, Texas

The City of Austin is a national leader in storm water management, with policies, ordinances and structural controls that are each more than 20 years old. Since 1998, Austin has undertaken a multi-year watershed master planning program. The purpose of the program is to integrate regulations, programs, and structural controls for flood protection, erosion prevention and water quality protection and enhancement. As part of the master planning process, hundreds of potential structural retrofit projects have been identified, including wet ponds, detention, constructed wetlands, media filters, bioretention swales, and streambank restoration. Wisdom from the Austin experience potentially applicable to reducing costs for Caltrans retrofit projects includes the following:

- Key tracts of land for structural retrofit BMPs are identified as quickly as possible in an urbanizing environment so that they can be purchased prior to development or further increases in land costs.
- Existing flood control infrastructure, such as detention ponds, are targeted for cost-effective retrofits. Such areas by their nature are located in hydrologically suitable sites, are often large scaled, have necessary inflow piping for water quality BMPs already in place, and require no or minimal acquisition costs if publicly owned.
- Retrofit projects are targeted to areas with high impervious levels and pollution loads.
- Because existing drainage facilities co-mingle the storm water contributions from a range of land use sources, retrofit projects treat waters emanating from a variety of owners and jurisdictions to achieve the overall goal of water quality improvement.
- Cost efficiencies of smaller-scaled solutions are sometimes competitive with regional scale solutions, when the negative environmental impacts of large-scale projects are considered.
- The master planning process allows the City to prioritize construction of the most cost-effective structural controls.
- The City expects to improve cost-effectiveness as more controls are designed, constructed, operated, and maintained.
- Programs and regulations are a necessary adjunct to, and in many cases cost less than, structural controls to achieve the City's water quality goals.

(2) Maryland State Highway Administration

Maryland State Highway Administration plans for future BMP projects well before these projects are actually constructed. When a later highway project (e.g., a lane or bridge addition) is to be constructed in the area targeted for runoff treatment, the BMP is integrated into the larger construction contract. This reduces the risk that optimal BMP sites will be overlooked in future projects. With this strategy, it is rare for a retrofit project to be built as a single item in a construction contract.

(3) Washington State DOT

WashDOT has developed a number of strategies to prevent storm water pollutants from reaching sensitive waterways to protect salmon as required by the Endangered Species Act. Starting in 1994, the department began investigating a systematic retrofit of all of its highway storm water outfalls. Retrofit projects were identified for 159 outfalls, all in Western Washington (where most of the state's rainfall and population occur). Each project was classified as "high," "medium," or "low" priority based upon receiving waters impacts. The projects averaged $300,000 and ranged from an estimated $15,000 to $6.5 million to construct. Retrofitting all 159 outfalls will cost $1.6 billion, according to very preliminary WSDOT staff estimates. Funding these projects has been difficult as the state legislature has not yet allocated the money; however, this may change with the stricter requirements being established to meet the ESA. (Molash, 2001; Xu, 2001)

b) Integrated BMPs

Many state transportation departments have developed criteria to integrate BMPs into their roadway infrastructure. This integration comes in the form both of combining the BMPs into other non-BMP projects and by selecting BMP technologies that can be more seamlessly incorporated into roadway drainage systems. Construction efficiencies can be achieved when BMP construction is part of a larger project, such as the reduction of mobilization costs. Bidding is significantly more competitive where the contract includes the familiar and profitable components of roadway construction, enhancement, or maintenance. Further savings can be achieved by specifying BMP technologies that replace existing drainage features and amenities (and associated costs) rather than represent a net addition to infrastructure and cost. Vegetated controls like biofilters and bioretention basins, for example, can be designed as landscaping elements. Vegetated swales can replace pipe conveyance in some locations. BMP integration into larger design decisions avoids redundancy and conflicts, and saves money.

(1) Maryland State Highway Administration

Maryland State Highway Administration plans to construct 20 structural BMP retrofit projects to meet NPDES permit requirements. The agency expressly avoids, however, building stand-alone retrofits. Maryland State Highway Administration combines retrofit BMP construction with other geographically proximate, if not adjacent, construction projects. Combining projects eliminates a separate procurement process, reduces mobilization, and achieves an economy of scale. While they could package the BMP projects together, Maryland State Highway Administration prefers to include them with other highway work. The reason is straightforward: “The contractors are attracted to the other highway work—that’s how they make their living. We would rather downplay, rather than highlight, the BMP portion since the other non-BMP construction activity matters more to the contractors and drives the project costs” (Veeramachaneni, 2000).

Maryland State Highway Administration’s goal is to totally integrate its BMPs into its highway designs. The extent of the integration depends upon the types of BMPs. End-of-pipe BMPs such as ponds do not necessarily require integration into a roadway. They are an additional element added on to a conventional drainage system. Maryland however is successfully experimenting with ways that BMPs can comprise the conveyance system itself. The “low impact development” BMPs used by Maryland State Highway Administration are good examples of these types of controls: swales, vegetative filter strips, in-line shallow marshes, and bioretention facilities. Maryland State Highway Administration also uses stream restoration projects to rehabilitate degraded stream channels and stream habitat and restore conveyance.

Maryland’s shift away from conventional, end-of-pipe BMPs was made in concert with changes in the Maryland Department of the Environment regulations to require systems that integrate natural stream protection with storm water management. Nonstructural practices and low impact development BMPs are now allowed and encouraged by the Maryland Department of the Environment’s regulations and the new Maryland Stormwater Design Manual (Maryland

Department of Environment, 2000). Maryland State Highway Administration has used these types of BMPs to create a new type of storm water system: a recent example is that of the construction of a segment of highway US 113 without large ponds. Instead, linear shallow marsh swales were installed to provide both conveyance and treatment. These marsh swales are located high in the watershed, near the source of runoff, rather than at the end-of-pipe. “It is quite possible to do this in a retrofit situation if the terrain and other constraints can be worked out,” says Veeramachaneni [2/26/01].

Maryland State Highway Administration has long used vegetated drainage swales and now plans to use pervious sidewalks, parking areas and alternative pavement materials to further integrate highway design for water quality benefits. Any space available is considered for small, dispersed BMP locations: pocket areas, often vegetated medians, tree islands, and other landscaped features. In planning to expand I-695 (the Baltimore Beltway), for example, existing drainage swales will be used for new water quality controls. Swales, bioretention facilities, and shallow ponding areas will be part of an integrated drainage system. BMP siting requirements for Maryland used to require locating large tracts of land for large-scaled BMPs—a difficult task in constrained highway right-of-way areas. But the use of integrated, vegetative BMPs helps solve this problem in some areas by enabling the construction of BMPs in very flexible sizes and shapes: “There are always opportunities at the micro-setting,” says Veeramachaneni. And vegetated BMPs serve both as water quality facilities and roadside beautification—money is saved by building and maintaining a combined feature rather than separate BMPs and landscaped areas.

Maryland is finding it increasing more difficult to isolate costs for these low impact development BMPs due to their integration into roadway expansion. This type of drainage infrastructure may actually save costs compared with conventional projects due to savings in other areas like downstream drainage pipe, and channels, which are smaller because of dispersed drainage designs and upslope placement of BMPs. The most regrettable cost, says Veeramachaneni, is that of a single storm water management device in a single location—it forces you to make a single solution work: an all-or-nothing proposition. By implementing controls at many points along runoff’s path, low impact development methods limit the runoff concentration, promote infiltration, preserve a more natural hydrologic regimen, and eliminate the need for a single solution to be effective. It appears to save money in the process.

c) BMPs for Redevelopment

Several state transportation departments require the use of BMPs for redeveloped portions of highway and other DOT infrastructure. Water quality controls are thereby added into projects that expand, alter, or even resurface roadways. Typically, an established threshold of impervious cover or disturbed area must be exceeded before controls are required. Delaware, Florida, Maryland, Minnesota, New Jersey, New York, Virginia, and Washington are states that require BMPs on redevelopment projects that increase existing amounts of impervious cover. All of these state transportation departments have developed cost-effective ways to build these controls, often in constrained urban locations. These departments find ways to implement retrofit BMPs, even if it is necessary to purchase relatively expensive land in commercial areas. These challenges have led to strategies that improve watersheds but not necessarily specific areas (see Compensatory Treatment/Storm water Banking below).

Note that BMPs built during the redevelopment of an existing roadway, parking lot, or maintenance station can fall into two categories: those that treat *only* new impervious cover added and those which treat *both* new impervious cover *and* preexisting areas. For this report, a **retrofit BMP** is defined as a control that receives runoff from a roadway that is not associated with a current or future construction project. A **redevelopment BMP** is one that receives runoff from existing developed areas associated with a current construction project. If a BMP collects and treats runoff only from newly developed areas (including modifications to an existing roadway, etc.), it would be termed a **new construction BMP**. New construction BMPs are not the subject of this report as they, unlike retrofits and redevelopment BMPs, do not address preexisting water quality problems.

(1) Washington State DOT

WSDOT has adopted what is known as the "140% rule." It states that where new construction projects are initiated (e.g., a lane addition or bridge replacement), an are equivalent to 140% of the new impervious surface area must be treated for water quality and quantity. The rule is geared towards effectiveness (no-net-increase in pollutant loading), based upon data showing that most BMPs remove a key indicator pollutant (Total Suspended Solids) at about a 70% rate (WSDOT, July 1999). The policy thus requires that all (100%) of the new impervious area plus an additional 40% of this area of *preexisting impervious surface* be treated. This effectively requires the retrofitting of existing areas. If an area this size cannot be treated by the project, a fee is paid to a Watershed Restoration Fund which in turn uses the money to fund other water quality and habitat restoration projects. WSDOT may have to raise the 140% requirement to 200% or even 250% to meet permitting requirements of the US Fish & Wildlife Service and the National Marine Fisheries Service for the Endangered Species Act (Molash, 2001). Such an increase would constitute a de facto increase in roadway retrofitting with BMPs.

The WSDOT *Highway Runoff Manual* establishes the following minimum requirement for all state projects: "BMPs for existing impervious runoff will be implemented whenever the investigation demonstrates that it would more feasible to construct the BMPs during the current project instead of waiting until a future date to fully retrofit the entire roadway section. BMPs for existing impervious runoff will also be installed whenever the benefit derived from immediately retrofitting the roadway can be shown to outweigh the cost of installing the BMPs" (WSDOT, 1995, p. 2-2). This requirement is to be met "to the maximum extent practicable;" in cases where such mitigation is determined to be not practicable, money must be paid to the Watershed Restoration Fund (further discussed in Compensatory Treatment/Storm water Banking below).

(2) City of Olympia, Washington

Olympia's storm water regulations require substantial water quality treatment for redeveloped properties—serves to retrofit existing developed lands which lack BMPs.

d) Regional BMP Deployment and Partnerships

National data show lower costs for large projects on a per unit basis. BMP cost studies conducted by Tom Schueler the Center for Watershed Protection demonstrate this relationship and these results have been accepted by the FHWA and EPA (Wiegand et al., 1986; Young et al., 1996; Brown and Schueler, 1997; Center for Watershed Protection, 1998; US EPA, 1999). Managers interviewed for departments of transportation agreed with this assessment: larger BMPs give lower per unit costs. Although permit conditions often require smaller scaled BMPs solely for a given project area, regional ponds are frequently preferred from a cost standpoint. Economies of scale are a dominant feature of most cost models (Molash, 2001).

Costs for storm water treatment may be lowered using regionally scaled BMPs, instead of multiple small-scaled BMPs. Some types of infrastructure can benefit from lower per unit costs for materials, equipment and labor. Recent studies have shown that larger wet, dry, and wetland pond facilities exhibit this tendency (US EPA, 1999; Brown and Schueler, 1997). Brown and Schueler (1997, p.7) note the following: "The total volume-BMP cost equations indicate that economies of scale prevail for all ponds and wetlands (i.e., the exponents in the equations are less than one). In other words, the larger the pond or wetland, the less expensive the facility on a per cubic foot of storage basis." Liao et al. (2001, p.1) summarize their findings: "The equations predict a significant construction cost decrease per unit cost with increasing basin or facility size for detention/retention basins and constructed wetlands."

Many storm water management departments including Maryland, Minnesota, Florida and Texas recognized this relationship and have devised strategies to build smaller numbers of larger facilities. Larger facilities are also viewed as more attractive because it is easier to operate and maintain a smaller number of large facilities than a larger number of small facilities, assuming that they are of the same technology.

Depending upon the sensitivity of receiving waters, large on-line BMP structures can have detrimental effects. They can block the natural flow of stream sediment and contribute to stream warming. Both of these effects negatively impacted downstream ecosystems. Maryland now favors smaller BMPs as noted in the Integrated BMPs section above (Veeramachaneni, personal communication). The City of Austin has recently come to the same conclusion, based on effects of large and instream systems on sediment transport and destruction of riparian woodlands from inundation. However, in these cases, the drainage areas of concern are very large (e.g., over 200 acres) in comparison to those seen in the Caltrans pilot program. Also, the receiving waters in many portions of Los Angeles are significantly modified and channelized and thus habitat, stream bank erosion, and flow regulation may not be of concern.
Highways and other linear landforms do not lend themselves to large scaled treatment. Drainage areas greater than 10 acres rarely exist within highway rights-of-way. Roadways are generally drained by a series of small drainage features, each connected to separate outfalls which commingle with runoff waters from neighboring land uses under separate regulatory jurisdictions.

Many other state transportation departments and other agencies use regional BMP facilities. Given the linear spatial characteristics of highways, cooperation with surrounding jurisdictional entities is generally required to develop regional facilities. Maryland, Minnesota, Virginia and Washington transportation departments actively consider regional BMP solutions with local county governments, cities, water districts or boards, and private property owners. The facility capital costs are apportioned between the various project participants according to either the percentage of drainage area acreage or the percentage of the total runoff to the facility. O&M responsibilities are generally assigned to a single entity. The Maryland State Highway

Administration, for example, has built BMPs in conjunction with adjacent private developers as well as with county governments. Maryland charges developers a lump sum fee for future maintenance. A special fund holds lump sum money for future operation and maintenance (Veeramachaneni, 2000). Virginia and Minnesota DOTs prefer to cede O&M responsibilities to the city and county governments with whom they partner where facilities are built off of department of transportation rights-of-way (J. Barrett and Mills, 2000; Larson, 2001).

e) Water Quality Banking/Compensatory Treatment

Several state transportation departments have developed policies that allow them to forego storm water treatment in a difficult area in exchange for equal treatment or over-treatment of a like area in a different area not included in the project. These systems are usually referred to as "Water Quality Banking" or "Compensatory Treatment." These arrangements were developed to lower project costs.

(1) Water Quality Banking in Maryland

Maryland established a water quality banking system in 1992 to allow certain highway projects to be constructed without water quality controls provided that equal or greater controls be constructed within the same watershed. The principle reason for the Bank's establishment was to control the costs of structural BMPs. A nomenclature used by financial banks was established to describe various aspects of the water quality bank: projects without water quality controls became "debits" and projects with additional water quality controls became "credits." The unit of measure is equivalent impervious acres.

Provisions limit the maximum debt within each "natural watershed," as established by the Maryland Department of the Environment. The Maryland State Highway Administration actively looks for cost-effective opportunities to provide storm water treatment beyond the minimum requirements. This strategy builds a pool of credit that can be used for projects located with difficult treatment challenges.

For example, in constructing ramps on I-95 (a major interstate highway), more acres were treated for water quality than were actually affected by the new construction. The project cost several million dollars and the marginal additional cost to treat other areas was minimal—much more cost effective than would be treating small projects for water quality in the future. Furthermore, the I-95 construction project would be very competitively bid by contractors. Because of the treatment of extra areas on this project, no treatment will be required for smaller projects in this watershed in the foreseeable future. Offsite mitigation (treatment of runoff from non-highway lands) is not usually credited at 100%: offsite mitigation in lieu of onsite controls generally requires more area to be treated. This provides an incentive for highway planners to look first to treating on-site to lower costs (e.g., because a smaller facility may be built) and thereby mitigate the direct impacts of the project. But if such opportunities are not favorable, the system allows a way to overtreat in another area to help offset the lack of onsite treatment. That greater net environmental benefit may be achieved with the Bank than with strict onsite treatment requirements is an important justification for the program. Although the program might be perceived as benefiting one area at the expense of another the additional area treated, the demonstrable net environmental benefit, cost reductions, and eliminating delays to projects has produced widespread praise and public acceptance.

Flexible implementation. Maryland's Water Quality Bank was developed in large part because the state wanted to achieve the benefits of retrofitting existing development—a major source of its water quality problems—without incurring the disproportionately high costs of building stand-alone retrofits. The Bank allows much greater latitude in site selection and encourages projects which address existing problems in conjunction with construction activities occurring for non-water quality reasons.

Real estate costs are very high in urban areas and greatly influence BMP costs. Maryland State Highway Administration, therefore, tries to do projects and buy land in more rural areas to save money. They look for the best sites for the lowest cost. The object is not to put in a BMP in a given area regardless of cost and feasibility, but to improve the condition of a given waterway. Flexible strategies, often employing the Water Quality Bank, are an excellent way to accomplish this goal.

Traffic control and maintenance costs, notes Veeramachaneni, are on of the largest expenses of highway retrofit projects, a cost which should be minimized whenever possible through planning with the Water Quality Bank. Where traffic safety issues are a concern, the department can focus on less-trafficked roads—basically, BMP sites should be prioritized by the safest and easiest. These projects should be done first, offering the most benefit for the least cost. And the department gains experience in how to best implement them as it goes along, given the flexibility of waiting for the best opportunities. Veeramachaneni provided the following example: if a project on a major highway (e.g., I-95) has enough room along the ROW, the department elects to treat the roadway using existing grassed swales rather than with new ponds. It considers it more cost-effective and beneficial for water quality to wait until later (using the Water Quality Bank) and implement the ponds as part of another, larger project rather than undertake a difficult project in a tough area as a retrofit (high traffic, little room for construction activities, high relative cost, etc.). "The retrofit would be a waste of money. In the meantime, while you wait for this [future] project, you focus your energies on implementing the easier projects in the best areas—more benefit for the money."

As noted above, Maryland State Highway Administration's NPDES permit requires that it build ten to twenty retrofit projects. The Water Quality Bank enables a very flexible mechanism in which to plan and build these facilities—in conjunction with other highway projects for economy of scale—to avoid the full cost of stand-alone retrofits.

(2) Other DOTs

The Virginia DOT water quality banking program is conceptually similar to Maryland's except that it allows for one-to-one treatment offsite to avoid high costs in one area. Overcompensation is not required. The compensatory treatment must occur in the same local drainage area and stream channel so as to account for the impacts of a given project on a given watershed (Mills, 2000). Florida DOT uses a water quality banking program with an informal goal of no net degradation of water quality. Minnesota DOT uses an informal system termed "Pond Banking" which shares costs among various regional entities as dictated by watershed districts. At times, highway runoff is allowed to go untreated in one area so long as requirements are exceeded in another area, sometimes not serving any MNDOT land but always exceeding the treatment level which would have had to be provided for the area untreated. Washington State DOT has a mechanism similar to a banking system called the Watershed Restoration Fund. Where projects cannot meet the required 140% treatment for new impervious surfaces (see "BMPs for Redevelopment" above), WSDOT contributes money to its Watershed Restoration Fund. This fund is used to construct other types of water quality controls elsewhere in the state. Typical projects include removal of fish barriers, riparian restoration, and cattle control for waterways (Molash, 2001). This arrangement is similar to the Maryland model in that they both shift runoff treatment from difficult areas to other easier ones, but the Washington version might take the money out of a given watershed and also addresses a broader set of water quality issues. Where highway BMPs are particularly expensive to construct, WSDOT is exploring cooperative arrangements that combine compensatory treatment systems with regional and multi-jurisdictional controls.

Note: It is possible that multiple participants could collaborate in a Water Quality Bank for a given region. Projects of each entity could be credited or debited as arranged by a consensus of its members. It would also be possible in this scenario for one or more entities to serve primarily or exclusively as funding agents for other participants within the system. This may be advantageous for a department of transportation in that its projects (on its linear rights-of-way) may be less likely to have the flexibility of onsite implementation than do other entities such as cities and counties which are comprised largely of residential, commercial, and industrial land uses. A larger variety of BMPs have been devised for urban, non-highway areas given the greater amount of space available and the lower level of traffic safety concerns.

f) BMP Technology Selection.

Both construction and operations and maintenance costs are a major factor in selecting BMP technology. Programs with several years of experience typically narrow the range of technologies and develop criteria for placing technologies in particular locations. These criteria include size of contributing area, size of area available for the control, the existing storm drainage system; and whether the BMP will be multifunctional.

The following BMP technologies with the following features are generally the least expensive in terms of life-cycle costs:

- Simple controls without pumps or other features that require frequent or complicated maintenance;
- Vegetative controls requiring minimum amounts of concrete construction;
- Controls built into existing landscaped features; and
- Controls that serve as part of the runoff conveyance as well as treatment system.

Specific cost-effective BMP technologies are discussed below.

Maryland State Highway Administration has generally found grassed channels to be the least expensive water quality control, with infiltration the next most economical. Grassed swales also are essentially "free" given that they are already installed as a matter of course in highway design and construction. Were actual retrofitting necessary, an average dry swale with an underdrain might cost approximately [illegible]000. As with other departments of transportation, Maryland finds real estate costs to be the most significant component of project cost. In 1992, a standard of $12,000 per impervious acre was judged to be a reasonable cutoff point for retrofits—anything more costly was considered infeasible and would require a different project to be developed using the water quality banking system. (This translates to approximately $18,000 per impervious acre in 1999 dollars for Los Angeles.) While this cost has gone up somewhat with inflation, it gives a sense of what Maryland considers to be unacceptably high.

Because BMP construction is now entirely integrated into larger roadway construction projects in Maryland, current exact costs are not readily available. For example, excavation costs for ponds are included as a portion of total excavation costs for a roadway and are not broken out as a separate line item. Maryland estimates stormwater control costs as a percentage of total project cost to be as follows:

- 5% for temporary erosion and sediment control. Maryland uses some of the most rigorous—and expensive—erosion and sedimentation controls in the country.
- 5-10% for permanent storm water BMPs.

Thus Maryland estimates costs of about 10-15% of total project cost on storm water controls. Estimates for WSDOT are similar to those for Maryland: permanent storm water BMPs cost about 5 to 10% of total project cost, with most tending toward the high end (10%). Delaware DOT also concurred with this 10% estimate (Palalay, 2000). North Carolina DOT, which is initiating work on a cost database, roughly estimated permanent control costs at 5% of total project cost. EPA estimates of 7% (NPDES implementation manual) are possibly low, especially for department of transportation projects on highways (Xu, 2001).

Maryland specifies the use of simple, vegetative controls whenever possible. This group of controls includes biofilter swales, biostrips (vegetated filter strips), and bioretention. These BMPs treat storm runoff as close to its point of generation as possible. The vegetation and infiltration treatment components mimic natural processes and can reduce the need for downstream drainage infrastructure and provide an aesthetic value in urban areas. Bioretention can be implemented with minimal land requirements, which saves on land costs and adds to flexibility of implementation. Larry Gavan of the Virginia Department of Conservation and Recreation estimates that approximately 900 square feet of bioretention basin are required per acre (43,560 square feet) of impervious surface (Gavan, 2000); this ratio is about what Prince George's County in Maryland, the pioneer of bioretention BMPs, also estimates (Coffman, 2000). This relatively small area (about 2% of the drainage area) is much lower than that required by many other structural BMPs and helps to lower costs and make this control more flexible to site. Maryland State Highway Administration discounts landscaping costs for vegetative BMPs from the total BMP costs because landscaping is required by the state even where no water quality controls are present. The net landscaping cost for vegetative BMPs is therefore low.

Maryland's use of diffuse controls is a strategy shared by a large number of other Departments of Transportation. Connecticut, Delaware, Massachusetts, Minnesota, New Jersey, New York, and

Washington State DOTs all have actively pursued design strategies to build small, decentralized vegetative controls where possible (with some simultaneously considering large-scaled regional facilities). This list of states also largely coincides with those who have the greatest experience implementing BMPs. (A large number of additional DOTs interviewed also use grassed swales as their principle BMPs (see Table III.1), though largely as a de facto, cost-effective control rather than as an engineered water quality solution.) Cost of construction and maintenance are usually the most important reasons for this approach. The linear form of highways also lends itself to the use of controls which handle sheet flow rather than concentrated flow (Greer, 8/1/2000). Ancillary benefits of improved aesthetics are also frequently cited.

The following BMP technologies are generally not considered cost-effective:

- Oil-grit separators, except for maintenance stations in vehicle maintenance areas. They are typically used only as a pretreatment device in front of another BMP or prior to discharge into a sanitary system.
- Drain inlet inserts (maintenance too frequent, expensive).
- Proprietary systems (e.g., StormFilters and CDS units).
- Any BMPs that are out of view and hard or unlikely to be maintained, like multi-chambered treatment trains and underground filters.

3. BMP Design and Value Engineering

a) Contributing Drainage Area Size

- Potential economy of scale savings (per discussion above "Regional BMP Deployment and Partnerships")
- Insert discussion of typical BMP sizes for a number of experienced DOTs.

b) Site Suitability/Compatibility

Site suitability and compatibility is viewed by experienced BMP designers as among the most critical elements for successful implementation and cost-effectiveness. One major BMP cost study conducted in Wisconsin concluded the following in developing its cost estimation guidelines: "For certain components, primarily excavation, clearing, and grubbing, inordinately high reported unit costs were not used in the calculation of the means and standard deviations. Sites with severe limitations may entail high costs; such sites should be considered as unsuitable locations for nonpoint source control measures. Many such measures can readily fail if not carefully designed and suitably located (SEWRPC, 1991)." In other words, site selection is so important that facilities built in highly suboptimal locations were not even considered as a basis to evaluate future BMP costs: such sites should be avoided as a matter of course and all available alternatives should be sought. This design consideration forms the basis for the many strategies discussed in the Planning section above to avoid problem sites and stand-alone retrofits in favor of regional controls and banking arrangements which help enable better, more consistent site selection and BMP compatibility.

Experienced departments have guidelines that help designers pick an appropriate BMP for a given site. The following sources were identified among the departments of transportation reviewed as useful tools for use in screening sites. Any given region, such as Southern California, would have to develop and adjust its own set of guidance criteria over time as more experience is gained relevant to unique geographical characteristics.

- 2000 Maryland Stormwater Design Manual. See Chapter 4.
- WSDOT Highway Runoff Manual. See Chapter 4.
- FHWA. Retention, Detention, and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. Volume I: Research Report. FHWA-RD-96-095, 1996. See especially Table 27, page 100.

Scale has an impact on cost-effectiveness for many BMP technologies. For example, some BMPs are most cost-effective for large drainage areas, while others are best for small drainage areas. Generally, pond or basin BMPs are not best suited for small sites (e.g., under 5 acres), with the possible exception of extended detention ponds, which have basic designs and are inexpensive relative to other pond technologies. Some stormwater departments are moving away from large, regional BMPs, preferring distributed systems for small, individual drainage areas. Given the limited availability of favorable large-scaled sites in urban areas, a pragmatic approach chosen by some is that of identifying and taking advantage of large region sites for use with large wet pond or wetland BMPs and, for all other sites, the use of small, distributed sites with vegetative BMPs and pocket ponds or bioretention filters (see BMP Technology Selection above).

c) Consideration of Full Range of BMPs

Experienced storm water quality managers have expanded the range of BMPs beyond typical structural controls, including:

- impervious cover removal;
- porous paving materials; and
- stream bank restoration, among others.

Some alternative techniques like alternative street designs to limit imperviousness, roof runoff capture, and green roofs, and are of limited value to a department of transportation. They could, however, be part of a regional partnership with a county or municipality wherein the department of transportation helps fund this work in lieu of direct controls.

d) Water Quality Volume

Available information indicates that the water quality capture volume used by state transportation departments typically varies over a fairly narrow range between 0.5 and one inch of runoff. Clear exceptions to this general rule are Minnesota, where capture volume ranges from 0.5 to 2.5 inches, and Washington State, where capture volume ranges from 0.5 to 3.5 inches. States express the capture volume design criteria in various ways:

- A percentage capture rule to capture a designated portion of total average annual runoff (Connecticut, Maryland, Vermont).
- A capture depth depending on BMP technology (Delaware, Florida, Maryland, Minnesota, Virginia).
- A capture depth depending on the sensitivity of receiving waters (Florida, Massachusetts, North Carolina).
- A capture volume based on runoff from a design storm (Maryland, Nevada, New York, Washington).

Some entities (e.g., the City of Austin) allow the use of flexible water quality volume requirements for retrofits. In such cases where a site is identified which cannot be cost-effectively retrofit according to standard criteria (usually applicable to new construction with fewer site constraints), City engineers consider smaller capture volumes with the assumption that reduced capture is preferable to none.

e) Use of Standardized Designs

Standardized designs and mass produced components may reduce costs by combining the best elements identified through experience and provide predictability for engineers and contractors. The following types of standardized designs are being used by storm water management entities:

- Precast concrete components.
- Use of existing construction components modified for BMPs (e.g., use of modified storm drain inlet boxes to make outlet structures for extended detention ponds, as with Virginia, Oregon DOT and others).
- Entire prefabricated BMP units (e.g., the proprietary systems, such as StormFilter, oil/water separators, drain inlet inserts, CDS units, etc.) to the extent applicable and cost-effective.

Precast components have been used extensively for Delaware sand filters and similar structures in the Mid-Atlantic region. Delaware DNREC reported a cost of $75,000 [adjust for region] per acre treated for Delaware sand filters. This compares favorably to the $520,893 per acre treated experienced for Caltrans' Escondido Delaware sand filter built for the pilot program. Some of this cost difference likely comes from the competitive costs made possible by the by precast production by Delaware manufacturers of the main vaults used for this device. (The Caltrans filter was cast in place.) The state of Delaware approves the production of these units by three different precasting companies (all of whom had a track-record of supplying quality inlets, manholes, etc.). Pitt et al. document interest on the part of precasters to develop pre-fabricated MCTT units: "These pre-fabricated units would likely be much less expensive and easier to install than the custom built units tested to date" (Pitt et al., 1999).

f) Materials Selection, Design Criteria and Specifications

The following materials, design criteria, and specifications have been found to generally result in cost effective water quality controls:

- small water quality volumes to capture only the first flush;
- use of natural materials like earthen embankments, bentonite linings, and rock rather than concrete;
- use of the least expensive materials;
- adequate site and geotechnical investigations;
- conveyance by gravity flow (Minnesota DOT actually uses microtunnels, a relatively expensive technology, to avoid the use of pumps);
- elimination of all fencing except where there are clear safety concerns;
- minimum and unpaved maintenance access roads with a stabilized construction entrance;
- plan for permanent barriers during design process to avoid redundant costs for temporary railing.

g) Vector Control Issues

Techniques used to control vectors include capping storage times at 72 hours (shorter than the time needed for mosquito larva to emerge from the water), introduction of mosquito controlling fish (e.g., *gambusia*) into BMP permanent pools, and location of controls away from residential areas. Vector control was not identified as a major issue by other storm water managers and did not represent a significant factor in the design or cost of BMPs.

h) Experience of Contractor

Most DOTs interviewed that have been constructing BMPs for more than 5 years or so experienced initial difficulty in working with contractors inexperienced with BMP construction. Research during the National Urban Runoff Program study 15 years ago compared bids from 15 different contractors on identical projects. This comparison documented that construction experience was the single most important factor in predicting bid costs: those with less experience tended to bid higher than those with more experience (Schueler, 2000).

i) Clarity of Bid Package

Some cost savings may occur by ensuring that bid packages are as clear (and therefore more attractive) as possible for contractors. Stormwater managers interviewed offered the following items as elements which they believed to help provide clarity, predictability and thereby lower the perceived risk on the part of contractors:

- Removal of unknowns and incidentals.
- Ensure all line items clear and precise.

- Provide specific, explicit quantities for all items.
- Describe elements included in every line item.
- Include standard details.
- Do not use lump sum items.
- Use competitive bidding process.
- Consider rejecting bids if bid prices higher than Engineer's Estimates and rework design to eliminate "extras."

C. Comparison of all BMP Technologies

A comparison between pilot program BMP costs experienced by Caltrans and those experienced by other agencies identifies differences and serves to indicate whether Caltrans might expect lower costs for future BMP construction. Cost comparisons between Caltrans and other entities' BMPs were made using these methods:

- All costs are adjusted for differences in regional economies using Means® *Heavy Construction Cost Data* (1999) and for differences in date of construction using the Environmental News Record (ENR) *Construction Index*.
- Geographical differences that might influence costs have been identified. Thus, if another entity has lower costs but does not retrofit and only builds controls in rural areas, that would be a critical difference. For some cases differences in climate and rain patterns are relevant cost factors.

Median costs per acre of contributing area for two groups and 15 BMP technologies are shown on Table 3-3. One group is the 153 BMPs from all entities, including Caltrans, for which cost data was obtained for this study. The second group is exclusively the 31 Caltrans pilot project sites.

Table 3-3 also presents the rank of the median cost per acre for each technology in each group. This table suggests that the lowest cost BMP per acre treated, without respect to performance, is generally achievable with inlet filters, wetlands, extended detention, and wet ponds. The highest cost per acre treated technologies are infiltration basins, Delaware sand filters, StormFilters, and the multi-chambered treatment trains.

Median costs for the Caltrans facilities are higher than median costs for the entire group for almost every technology. This cost difference is partly a function of the smaller drainage areas for the Caltrans pilot project BMPs, and partly a function of higher costs for the same-sized or larger drainage area.

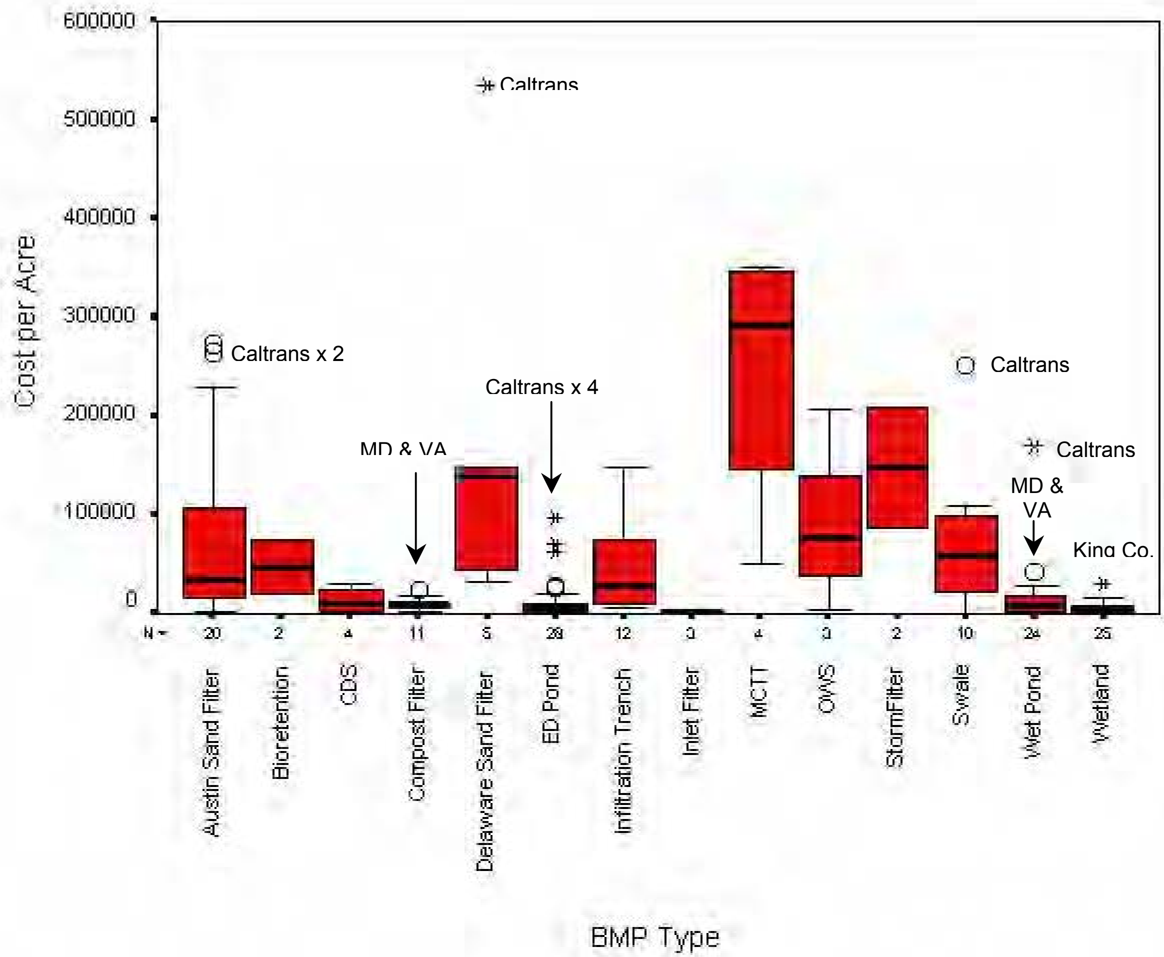
Similar, but more detailed information is shown in Figure 3-2, a boxplot of costs per acre treated for each technology type. The black line through the middle of the box is the median. The top and bottom of the box are the first and third quartiles. The horizontal lines above and below the box are the lowest and highest observations that are not more than 1.5 box lengths from the box.

Circles mark outliers, observations that are 1.5 to 3 box lengths from the box. Stars mark extreme values, more than 3 box lengths from the box. For several of the BMP technologies, Caltrans costs per acre were outliers or extreme values in this data set.

Table 3-3. Summary of Median BMP Costs per Acre

	Caltrans and other Entities			Caltrans		
BMP Technology	**Number of Facilities**	**Median Cost/ Acre Contributing Area**	**Median Cost/ Acre Rank**	**Number of Facilities**	**Median Cost/ Acre Contributing Area**	**Median Cost/ Acre Rank**
Inlet Filter	3	$ 1,977	1	3	$ 1,977	1
Wetland	25	$ 3,667	2	0	---	---
ED Pond	28	$ 4,348	3	5	$ 62,905	3
Wet Pond	24	$ 6,322	4	1	$ 169,275	7
CDS	4	$ 9,674	5	2	$ 22,458	2
Compost Filter	11	$ 10,016	6	0	---	---
Infiltration Trench	10	$ 14,712	7	2	$ 135,555	6
Austin Sand Filter	20	$ 33,257	8	5	$ 228,440	10
Bioretention Filter	2	$ 46,154	9	0	---	---
Swale	10	$ 58,941	10	6	$ 90,088	5
OWS	3	$ 73,992	11	1	$ 206,303	8
Infiltration Basin	2	$ 74,911	12	2	$ 74,911	4
Delaware Sand Filter	5	$ 138,016	13	1	$ 535,552	12
StormFilter	2	$ 147,710	14	1	$ 209,299	9
MCTT	4	$ 290,884	15	2	$ 290,884	11

Figure 3-2. Boxplot of Costs per Acre Treated for Each Technology Type



D. Discussion by BMP Technology

1. Austin Sand Filter

Five of the Caltrans pilot retrofit project BMPs were Austin sand filters. The Cost Project Study Team obtained costs and contributing area sizes for 15 additional Austin sand filter BMPs installed by other entities. Costs for these BMPs are summarized in Table 3-4 and Figure 3-3. Caltrans pilot project costs for this technology are similar to, or lower than costs for the City of Austin or TxDOT. For facilities with costs between $300,000 and $350,000, however, TxDOT facilities are treating larger contributing areas. On a per acre treated basis, the cost for the Caltrans facility is $228,000 per acre, compared to about $50,000 per acre for the TxDOT facility. Costs per acre treated for the Caltrans Austin sand filter projects are generally higher than for all other entities for which data were obtained.

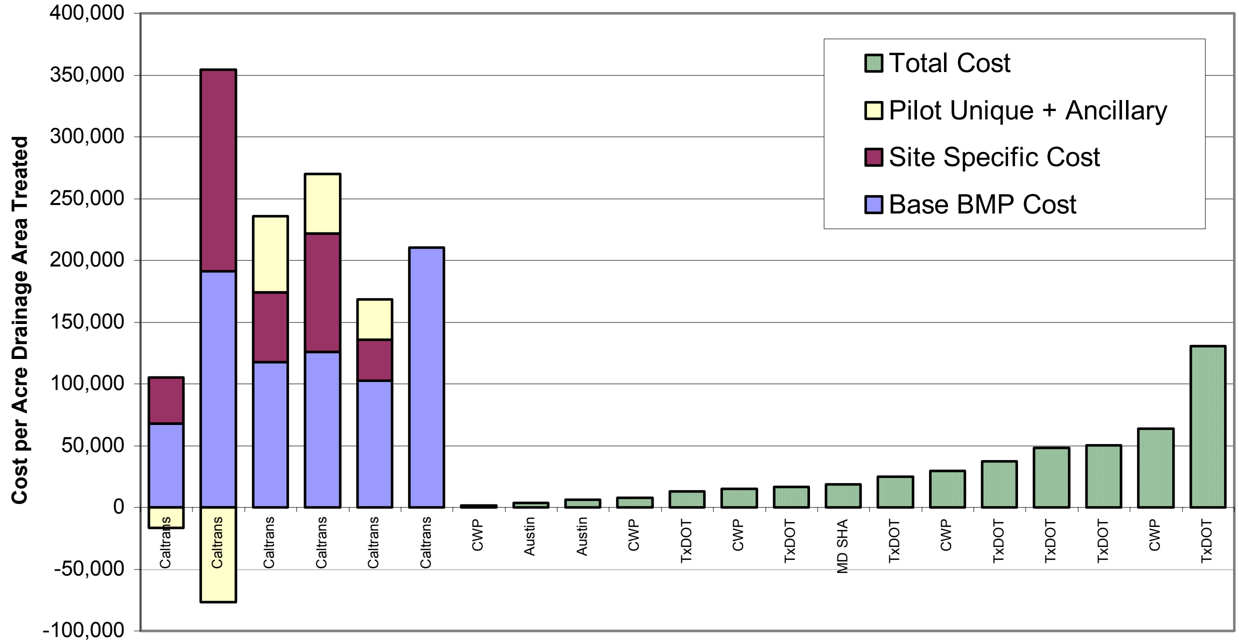
Compared to other technologies, median costs per acre for the Austin sand filter are in the middle of the range of technologies, ranked 8 out of 15 (see Table 3-4). As implemented for the Caltrans pilot retrofit project, however, they are more expensive than other technologies. Median costs per acre treated rank 10 out of 12. [Insert additional site-specific observations.]

Table 3-4. Austin Sand Filter Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	13.60	4,008	$ 18,970	$ 1,395
City of Austin	32.00	-	$ 115,553	$ 3,611
City of Austin	66.00	-	$ 410,701	$ 6,223
Maryland & Virginia CWP	2.90	1,617	$ 22,825	$ 7,871
TxDOT	96.25	193,362	$ 1,232,608	$ 12,806
Maryland & Virginia CWP	2.10	7,224	$ 31,431	$ 14,967
TxDOT	241.05	-	$ 4,007,301	$ 16,624
MD SHA	2.06	3,740	$ 38,201	$ 18,544
TxDOT	70.82	-	$ 1,763,513	$ 24,901
Maryland & Virginia CWP	2.00	478	$ 58,629	$ 29,315
TxDOT	86.42	163,300	$ 3,214,831	$ 37,200
TxDOT	6.25	14,088	$ 301,293	$ 48,207
TxDOT	6.01	15,585	$ 301,293	$ 50,132
Maryland & Virginia CWP	0.50	7,363	$ 31,798	$ 63,597
Caltrans	2.80	10,019	$ 231,625	$ 82,723
TxDOT	9.80	26,740	$ 1,281,751	$ 130,791
Caltrans	2.80	7,841	$ 463,461	$ 165,522
Caltrans	1.50	3,920	$ 342,660	$ 228,440
Caltrans	1.80	7,841	$ 476,106	$ 264,504
Caltrans	0.80	3,920	$ 217,587	$ 271,984

*All costs adjusted to LA region, 1999.

Figure 3-3. Austin Sand Filter Costs



2. Bioretention Filter

Caltrans installed no bioretention filters. Data were obtained for two biorentention BMPs installed by the Maryland State Highway Administration. These data are summarized in Table 3-5. Median costs per acre treated for bioretention ranked 9 out of 15 technologies. [Insert additional site-specific observations.]

Table 3-5. Bioretention Filter Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
MD SHA	4.24	1" over DA	$ 82,206	$ 19,388
MD SHA	2.30	35,000	$ 167,716	$ 72,920

*All costs adjusted to LA region, 1999

3. Compost Filter

Compost filters are a variation on the sand filter technology. Caltrans installed no compost filters. Data obtained from Maryland and Virginia by the Center for Watershed Protection is presented in Table 3-6. The median cost per acre for this technology is $10,016, which ranked sixth out of 15 technologies.

Table 3-6. Compost Filter Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	73.00	-	$ 196,155	$ 2,687
Maryland & Virginia CWP	11.70	9,148	$ 40,769	$ 3,485
Maryland & Virginia CWP	4.70	2,200	$ 24,604	$ 5,235
Maryland & Virginia CWP	4.40	11,780	$ 23,700	$ 5,386
Maryland & Virginia CWP	1.10	-	$ 10,299	$ 9,363
Maryland & Virginia CWP	1.00	-	$ 10,016	$ 10,016
Maryland & Virginia CWP	3.40	-	$ 35,863	$ 10,548
Maryland & Virginia CWP	1.10	-	$ 11,651	$ 10,592
Maryland & Virginia CWP	2.70	-	$ 28,873	$ 10,694
Maryland & Virginia CWP	1.70	-	$ 29,858	$ 17,563
Maryland & Virginia CWP	0.50	-	$ 11,687	$ 23,375

*All costs adjusted to LA region, 1999

4. Continuous Deflection Separators

Caltrans installed two continuous deflection separators. The Cost Study Team identified and obtained data for two additional installations by the Florida Department of Environmental Protection and by the City of Santa Monica. Information obtained is summarized in Table 3-7. Costs ranged from $31,684 to $312,103. The drainage areas served ranged from 1.09 to 90 acres and the cost per acre from $1,800 to $29,000.

Based on data from all entities, the median cost per acre for this BMP technology is $9,700. It is ranked fourth of 15 technologies, in terms of cost per acre. Looking exclusively at the Caltrans pilot project BMPs, the median cost per acre is higher, $22,458. It is, however, second of 12 technologies. [Insert additional site-specific observations.]

Table 3-7. Continuous Deflection Separator Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft^3)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Florida DEP	40.00	-	$ 72,416	$ 1,810
Santa Monica	90.00	-	$ 312,103	$ 3,468
Caltrans	2.52	-	$ 40,024	$ 15,880
Caltrans	1.09	-	$ 31,684	$ 29,036

*All costs adjusted to LA region, 1999

5. Delaware Sand Filter

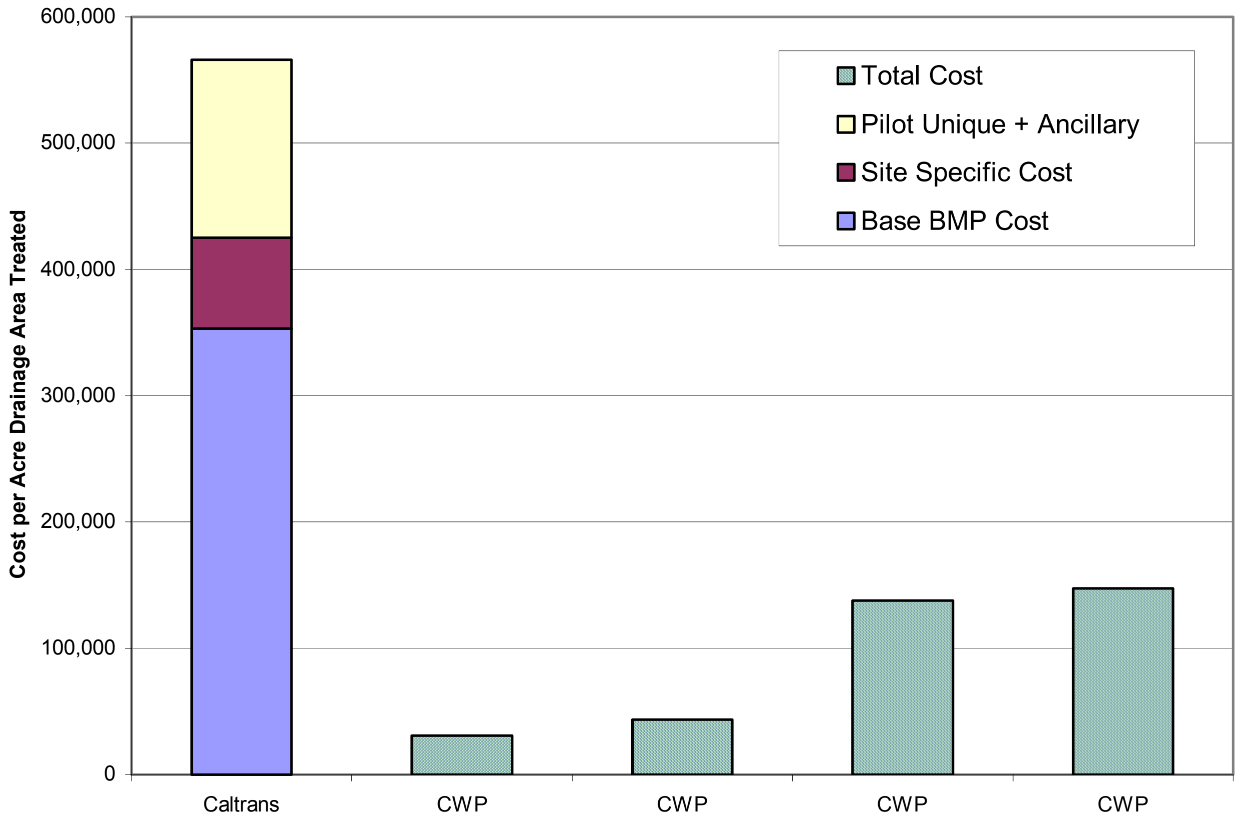
Caltrans installed one Delaware sand filter. Information on four additional Delaware sand filters was obtained. Summary information for these five BMPs is presented in Table 3-8 and Figure 3-4. All five of these units serve small drainage areas ranging in size from 0.62 to 1.60 acres. Caltrans costs per acre treated are 3.6 times the next most expensive facility. Of the technologies installed for the pilot retrofit project, the Delaware Sand Filter had the highest median cost per acre treated. Based on a combination of cost information from Caltrans and other entities, the median cost per acre treated ranks 13 out of 15 BMP technologies. [Insert additional site-specific observations.]

Table 3-8. Delaware Sand Filter Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft^3)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	0.62	103	$ 19,111	$ 30,824
Maryland & Virginia CWP	1.60	2,933	$ 69,524	$ 43,452
Maryland & Virginia CWP	1.30	9,313	$ 179,421	$ 138,016
Maryland & Virginia CWP	1.30	11,752	$ 191,893	$ 147,610
Caltrans	0.80	436	$ 428,442	$ 535,552

*All costs adjusted to LA region, 1999

Figure 3-4. Delaware Sand Filter Costs



6. Extended Detention Pond

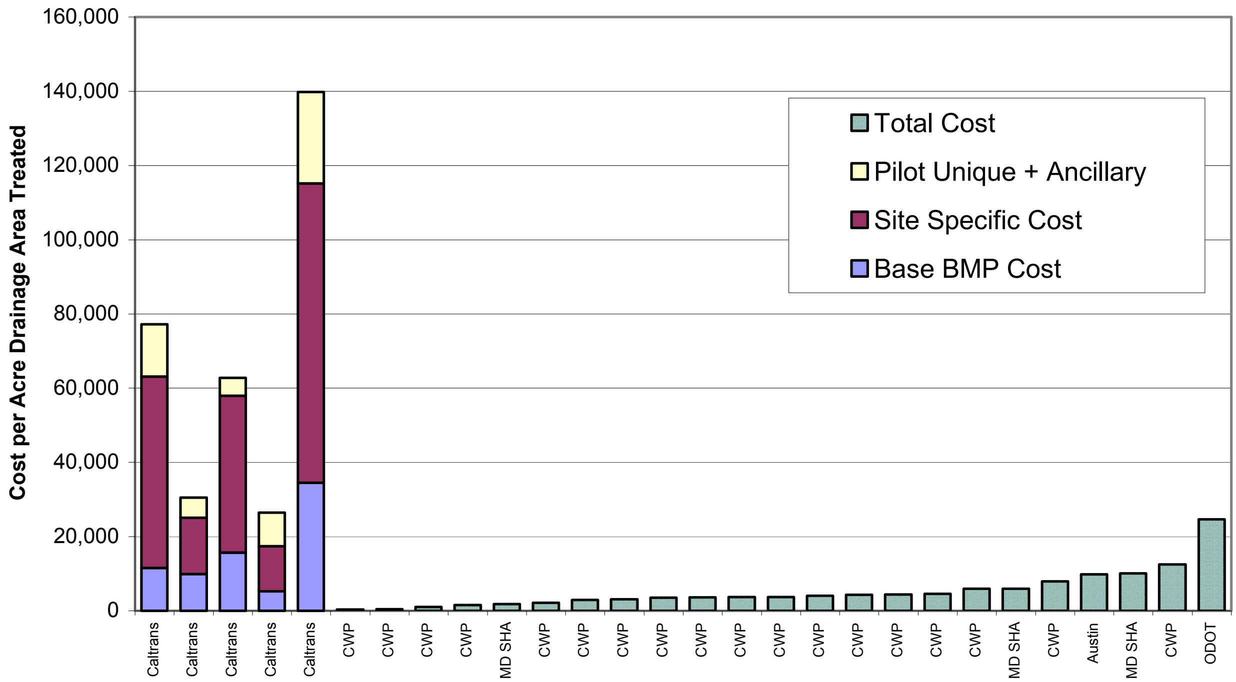
Caltrans constructed five extended detention facilities. Information was obtained for 23 additional sites. Summary information for these 28 extended detention BMPs is summarized in Table 3-9 and Figure 3-5. The median cost per acre treated for five Caltrans sites was $62,905. Median costs per acre treated for all entities, including Caltrans, is $4,348. Based on either the Caltrans pilot retrofit project, or data from all sites, extended detention is a relatively inexpensive technology, in terms of cost per acre treated. It ranks third out of 12 or 15 different BMP technologies, respectively. [Insert additional site-specific observations.]

Table 3-9. Extended Detention Pond Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	35.00	16,155	$ 12,558	$ 359
Maryland & Virginia CWP	77.90	36,435	$ 34,882	$ 448
Maryland & Virginia CWP	380.80	1,434,431	$ 382,556	$ 1,005
Maryland & Virginia CWP	201.00	483,516	$ 314,033	$ 1,562
MD SHA	145.31	253,200	$ 267,680	$ 1,842
Maryland & Virginia CWP	3.10	5,663	$ 6,813	$ 2,198
Maryland & Virginia CWP	2.30	7,841	$ 6,813	$ 2,962
Maryland & Virginia CWP	25.00	222,447	$ 78,536	$ 3,141
Maryland & Virginia CWP	59.10	655,523	$ 210,793	$ 3,567
Maryland & Virginia CWP	4.50	9,200	$ 16,464	$ 3,659
Maryland & Virginia CWP	10.90	36,590	$ 40,752	$ 3,739
Maryland & Virginia CWP	44.30	187,308	$ 165,652	$ 3,739
Maryland & Virginia CWP	4.30	11,258	$ 17,507	$ 4,071
Maryland & Virginia CWP	19.50	100,188	$ 83,875	$ 4,301
Maryland & Virginia CWP	3.10	10,600	$ 13,626	$ 4,396
Maryland & Virginia CWP	229.90	3,571,920	$ 1,041,912	$ 4,532
Maryland & Virginia CWP	3.20	28,314	$ 19,091	$ 5,966
MD SHA	6.60	3,000	$ 39,388	$ 5,968
Maryland & Virginia CWP	3.70	22,651	$ 29,319	$ 7,924
City of Austin	130.00	-	$ 1,282,221	$ 9,863
MD SHA	15.41	61,500	$ 155,706	$ 10,104
Maryland & Virginia CWP	16.50	222,156	$ 206,571	$ 12,519
Caltrans	6.80	13,068	$ 127,202	$ 18,706
ODOT	2.90	-	$ 71,540	$ 24,669
Caltrans	5.30	13,939	$ 147,595	$ 27,848
Caltrans	13.40	39,640	$ 842,925	$ 62,905
Caltrans	4.80	8,712	$ 339,116	$ 70,649
Caltrans	0.80	2,614	$ 77,389	$ 96,737

*All costs adjusted to LA region, 1999

Figure 3-5. Extended Detention Pond Costs



7. Infiltration Basin

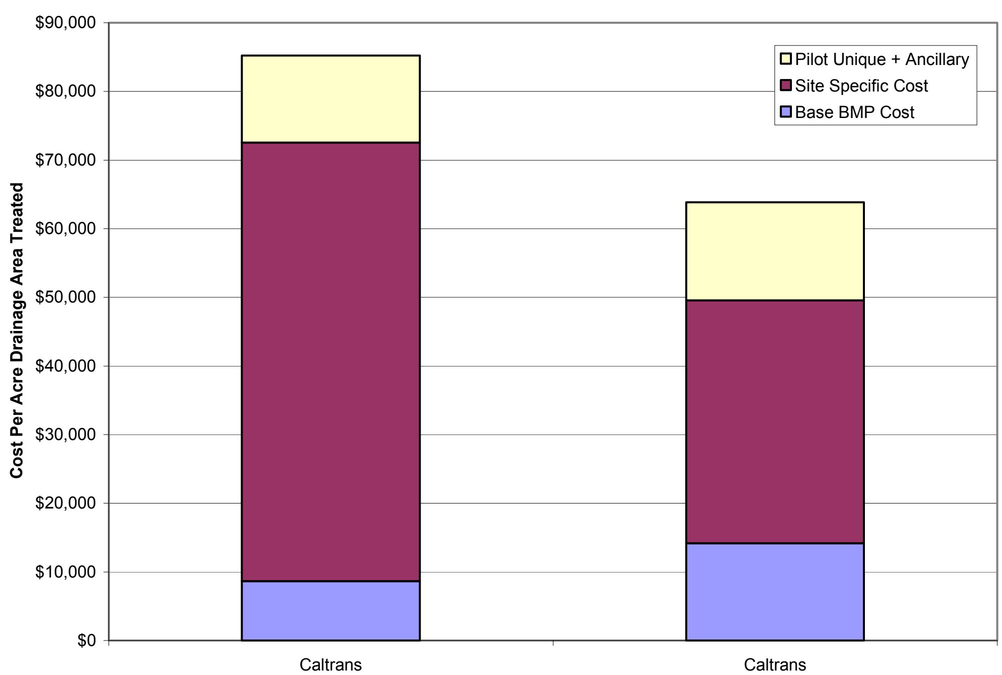
Caltrans constructed two infiltration basins. No information was obtained for this type of technology from other entities. Information for the Caltrans BMPs is summarized in Table 3-10 and Figure 3-6. The median cost per acre treated for this technology was $74,911. It is relatively inexpensive compared to other Caltrans retrofit costs, ranking fourth out of 12. Compared to costs for other technologies experienced by other entities, however, Caltrans infiltration basin costs rank 12 out of 15. [Insert additional site-specific observations.]

Table 3-10. Infiltration Basin Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Caltrans	4.20	15,246	$ 267,980	$ 63,805
Caltrans	3.20	8,712	$ 275,259	$ 86,018

*All costs adjusted to LA region, 1999

Figure 3-6. Infiltration Basin Costs



8. Infiltration Trench

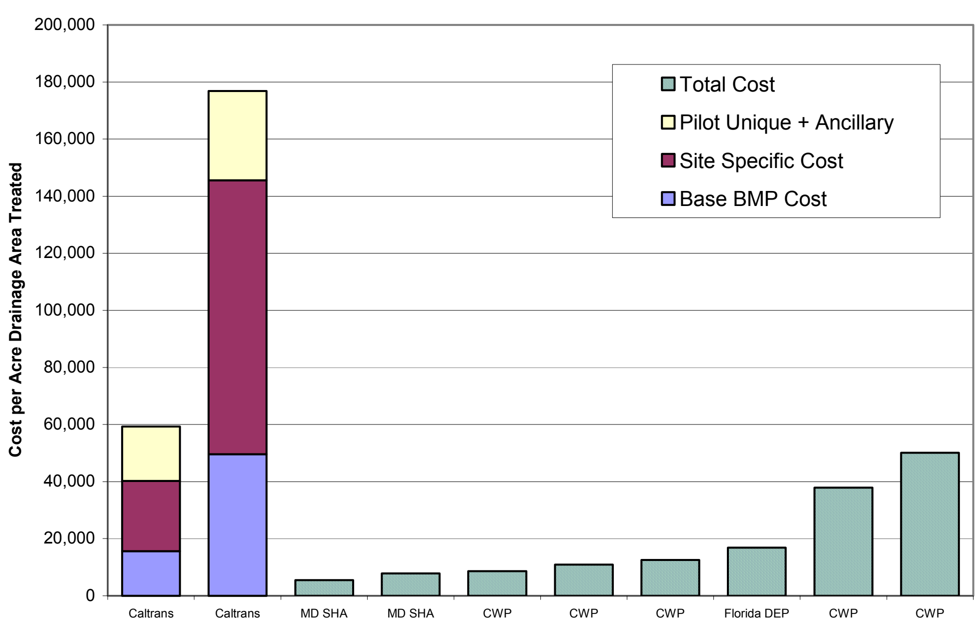
Caltrans constructed two infiltration trenches and information was obtained for eight infiltration trenches installed by other entities. Information for these BMPs is summarized in Table 3-11 and Figure 3-7. The median cost per acre for all infiltration trenches for which data was obtained was $14,712. The median cost per acre treated for the Caltrans infiltration trenches was $135,555. Despite the difference in median costs per acre treated, this technology ranked in the middle of the both sets of median values. [Insert additional site-specific observations.]

Table 3-11. Infiltration Trench Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
MD SHA	7.71	15,900	$ 41,921	$ 5,437
MD SHA	6.80	12,342	$ 53,192	$ 7,822
Maryland & Virginia CWP	0.62	1,880	$ 5,362	$ 8,649
Maryland & Virginia CWP	0.92	446	$ 10,084	$ 10,961
Maryland & Virginia CWP	0.54	1,346	$ 6,766	$ 12,529
Florida DEP	49.00	30,700	$ 827,808	$ 16,894
Maryland & Virginia CWP	0.20	1,900	$ 7,571	$ 37,854
Maryland & Virginia CWP	0.59	706	$ 29,589	$ 50,151
Caltrans	1.70	6,098	$ 208,044	$ 122,379
Caltrans	1.70	6,098	$ 252,845	$ 148,732

*All costs adjusted to LA region, 1999

Figure 3-7. Infiltration Trench Costs



9. Inlet Filter

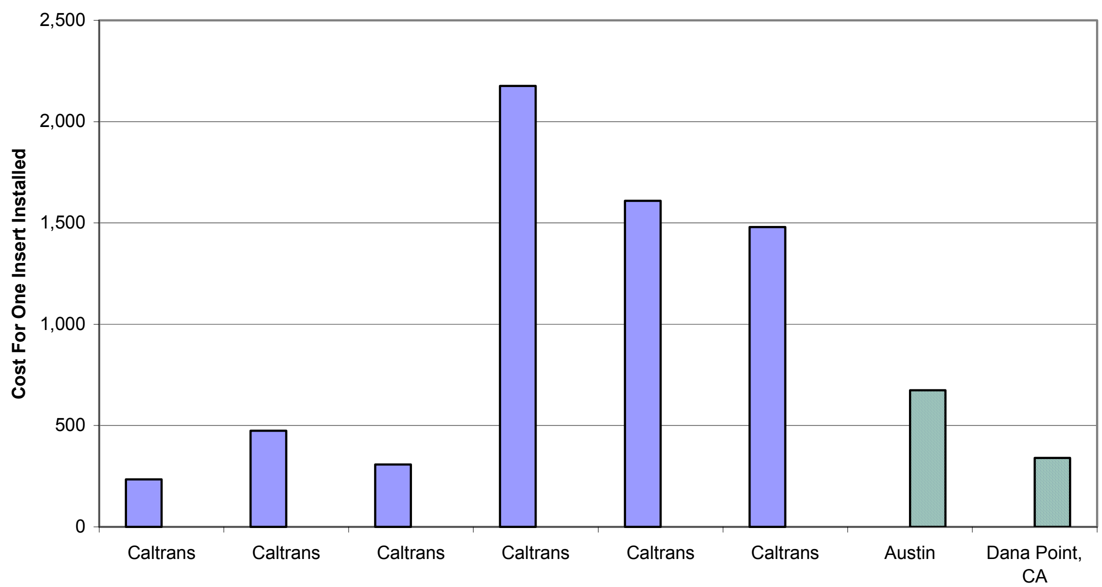
Information was obtained only for the three Caltrans inlet filters. Each cost $2,372 and there are differences in the cost per acre treated only due to the different contributing areas to each inlet (see Table 3-12 and Figure 3-8). This technology costs the least of those considered in this study. [Insert additional site-specific observations.]

Table 3-12. Inlet Filter Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Caltrans	1.60	5,663	$ 2,372	$ 1,482
Caltrans	1.20	4,356	$ 2,372	$ 1,977
Caltrans	0.80	3,049	$ 2,372	$ 2,965

*All costs adjusted to LA region, 1999

Figure 3-8. Inlet Filter Costs



10. Multi-Chamber Treatment Train

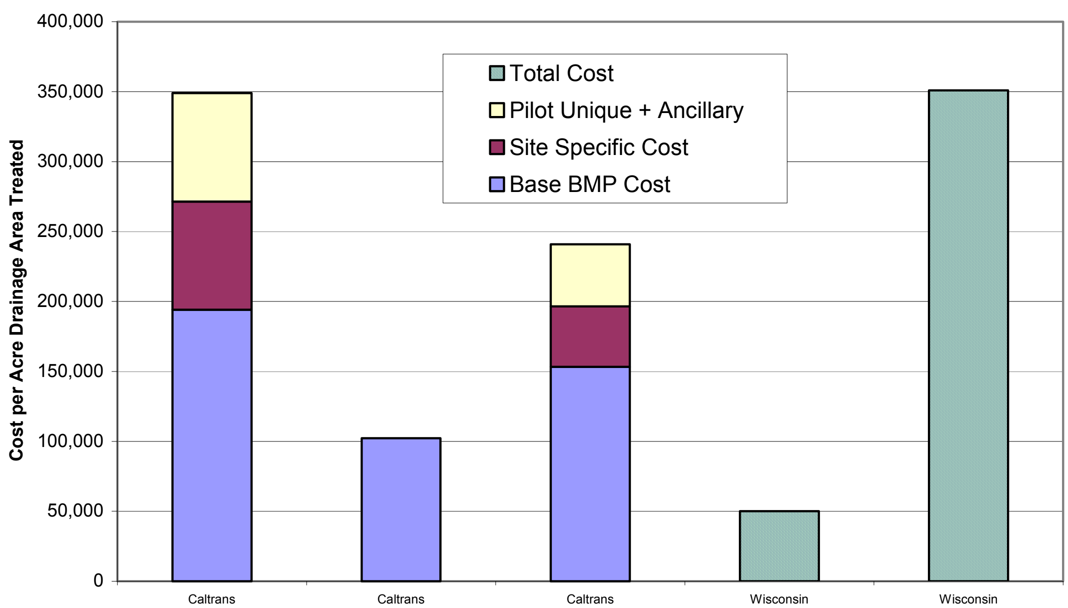
Caltrans constructed two multi-chamber treatment trains and information was obtained for two other constructed in Wisconsin. Data for these four systems is summarized in Table 3-13 and Figure 3-9. Caltrans costs for these units ranged from about three to five times those for the Wisconsin systems. Of the 15 technologies for which information was obtained, median costs per acre treated were highest for the multi-chamber treatment train technology. [Insert additional site-specific observations.]

Table 3-13. Multi-Chamber Treatment Train Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Wisconsin	2.50	-	$ 125,320	$ 50,128
Caltrans	1.90	6,098	$ 456,567	$ 240,298
Caltrans	1.10	4,356	$ 375,617	$ 341,470
Wisconsin	0.25	-	$ 87,724	$ 350,896

*All costs adjusted to LA region, 1999

Figure 3-9. Multi-Chamber Treatment Train Costs



11. Oil-Water Separator

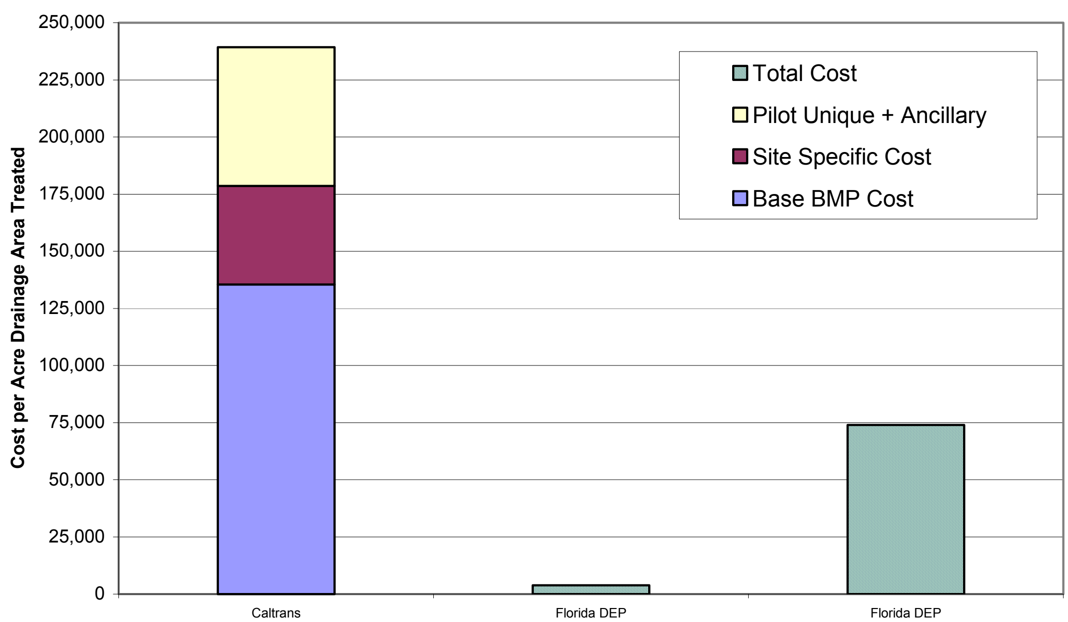
Caltrans constructed one oil-water separator and information was obtained for two other systems installed by the Florida Department of Environmental Protection. Information for the three systems is summarized in Table 3-14 and Figure 3-10. Of the three units, the Caltrans facility is the least expensive. The drainage for the Caltrans unit, however, is much smaller than the drainage area for the other units. On a cost per acre treated it is, therefore, more than twice as expensive as the next most expensive unit. This technology is relatively expensive, with a median cost per acre treated that ranks 11 out of 15 for data for all entities, and 8 out 12 for Caltrans data. [Insert additional site-specific observations.]

Table 3-14. Oil/Water Separator Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Florida DEP	49.00	-	$ 191,247	$ 3,903
Florida DEP	5.00	-	$ 369,958	$ 73,992
Caltrans	0.80	2,178	$ 165,043	$ 206,303

*All costs adjusted to LA region, 1999

Figure 3-10. Oil/Water Separator Costs



12. StormFilter

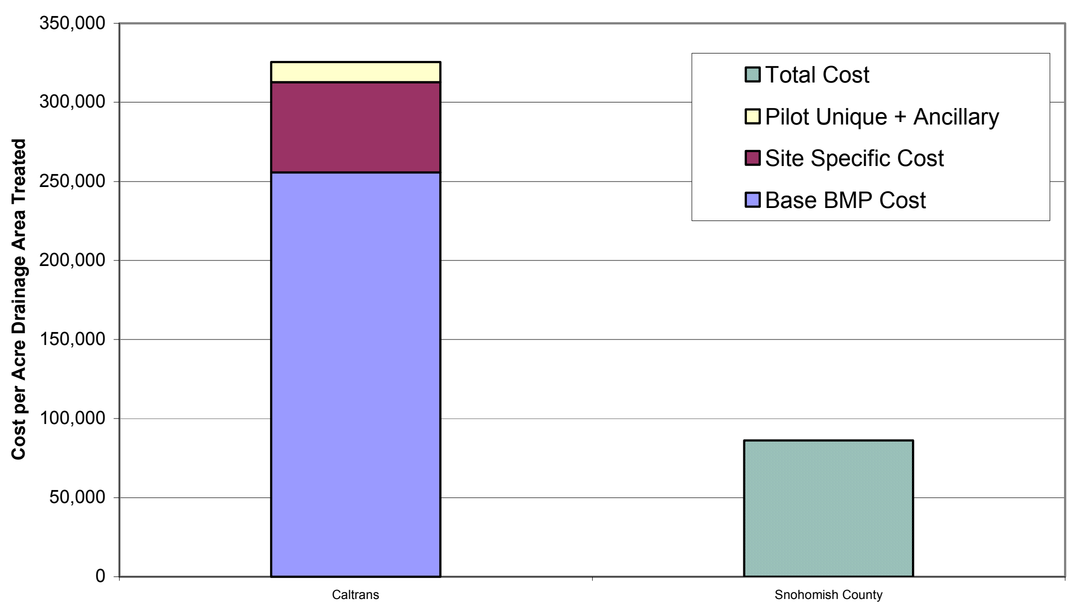
Caltrans installed one StormFilter BMP and data was obtained for another StormFilter installed in Snohomish County, Washington. Summary information is presented in Table 3-15 and Figure 3-11. The Caltrans StormFilter BMP cost more than 16 times the one installed in Washington. It treats a slightly larger drainage area. Compare to other technologies, StormFilters are relatively expensive in terms of cost per acre treated, ranking 14 out 15 for all of the data, and 9 out of 12 for the Caltrans BMPs. [Insert additional site-specific observations.]

Table 3-15. StormFilter Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Snohomish County	0.22	50	$ 18,947	$ 86,121
Caltrans	1.50	4,522	$ 313,948	$ 209,299

*All costs adjusted to LA region, 1999

Figure 3-11. StormFilter Costs



13. Swale

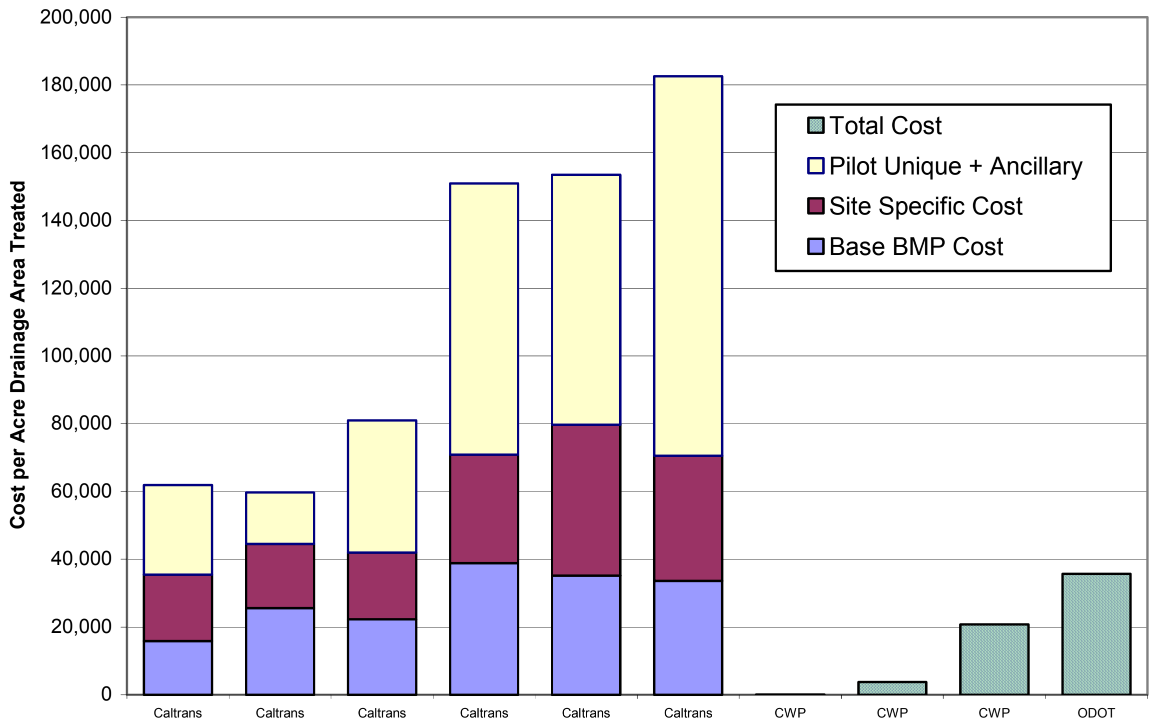
Caltrans installed six swales and data from other entities was obtained for four more. Summary information is presented in Table 3-16 and Figure 3-12. The median cost per acre treated was $58,941 for all entities. This technology ranks relatively high compared to the median cost per acre for all technologies, 10 out of 15. The median cost per acre of $90,088 for the Caltrans swales ranked fifth out of 12 technologies based on median costs for the Caltrans retrofit pilot projects. Cost per acre treated for the Caltrans swales was higher than that for other entities. [Insert additional site-specific observations.]

Table 3-16. Swale Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	80.00	-	$ 3,561	$ 45
Maryland & Virginia CWP	5.00	-	$ 18,932	$ 3,786
Maryland & Virginia CWP	0.87	6,778	$ 18,089	$ 20,792
ODOT	1.17	-	$ 41,736	$ 35,672
Caltrans	2.40	6,916	$ 136,822	$ 57,009
Caltrans	2.30	6,650	$ 140,006	$ 60,872
Caltrans	0.40	1,742	$ 31,992	$ 79,979
Caltrans	0.70	2,614	$ 70,138	$ 100,197
Caltrans	0.70	2,178	$ 76,179	$ 108,827
Caltrans	0.50	1,742	$ 125,488	$ 250,977

*All costs adjusted to LA region, 1999

Figure 3-12. Swale Costs



14. Wet Pond

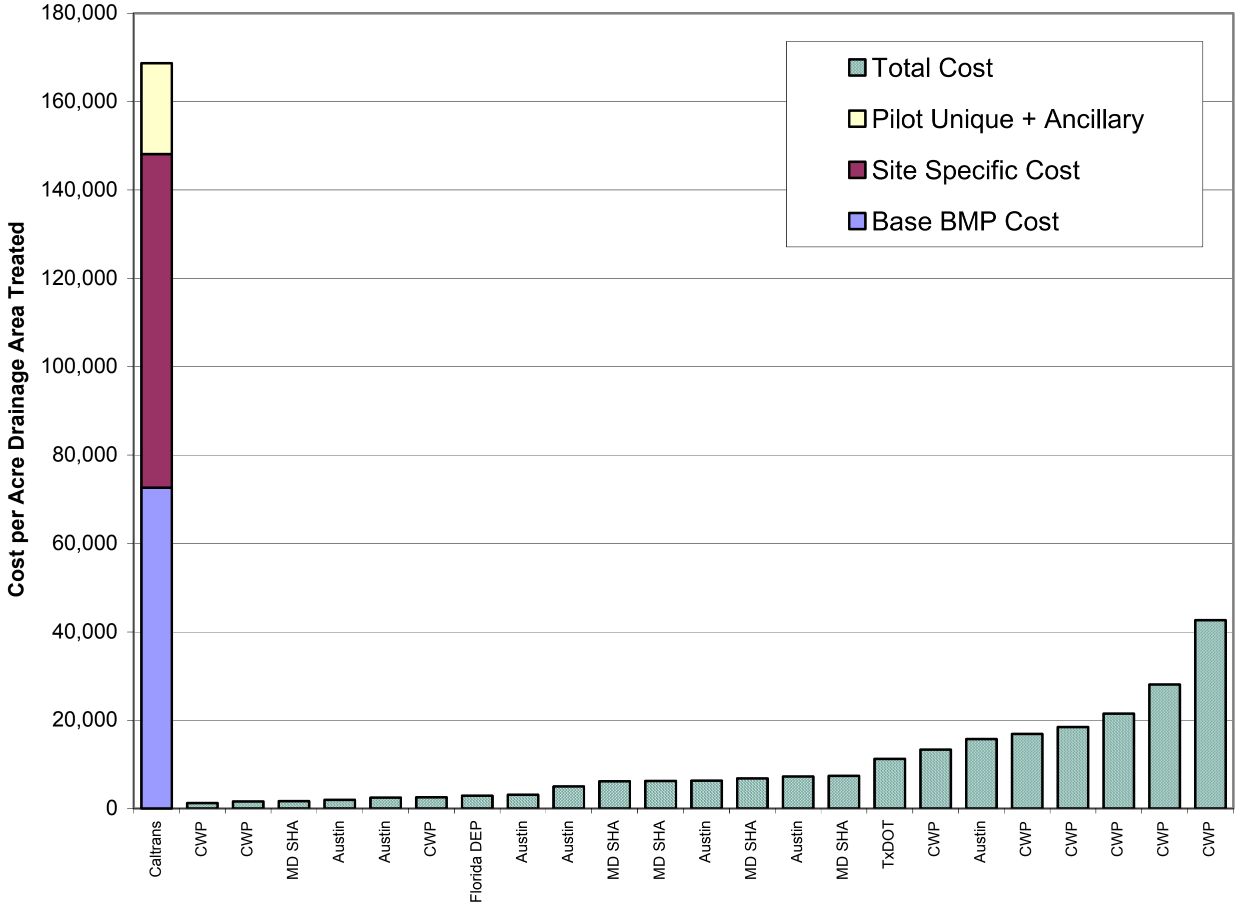
Caltrans constructed 1 wet pond as part of the retrofit pilot project and information was obtained for 23 wet pond BMPs constructed by other entities. Summary information is presented in Table 3-17 and Figure 3-13. The median cost per acre treated for this technology was $6,322 for all entities and ranked fourth out of 15. The cost per acre treated for the Caltrans facility was $169,275, which ranked seventh out of 12 technologies. [Insert additional site-specific observations.]

Table 3-17. Wet Pond Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	82.10	22,433	$ 101,785	$ 1,240
Maryland & Virginia CWP	36.00	130,680	$ 57,067	$ 1,585
MD SHA	143.00	171,000	$ 235,955	$ 1,650
City of Austin	462.00	-	$ 912,362	$ 1,975
City of Austin	907.00	-	$ 2,221,441	$ 2,449
Maryland & Virginia CWP	22.10	101,930	$ 56,155	$ 2,541
Florida DEP	390.00	-	$ 1,125,538	$ 2,886
City of Austin	109.00	-	$ 335,748	$ 3,080
City of Austin	173.00	-	$ 865,656	$ 5,004
MD SHA	13.70	30,000	$ 84,623	$ 6,177
MD SHA	11.85	23,100	$ 73,743	$ 6,223
City of Austin	78.00	-	$ 493,151	$ 6,322
MD SHA	15.62	51,400	$ 106,384	$ 6,811
City of Austin	57.00	-	$ 412,329	$ 7,234
MD SHA	37.40	59,000	$ 275,480	$ 7,366
TxDOT	64.00	-	$ 718,027	$ 11,219
Maryland & Virginia CWP	2.80	22,651	$ 37,206	$ 13,288
City of Austin	72.00	-	$ 1,128,870	$ 15,679
Maryland & Virginia CWP	12.80	91,476	$ 215,941	$ 16,870
Maryland & Virginia CWP	15.30	113,256	$ 282,133	$ 18,440
Maryland & Virginia CWP	12.30	122,804	$ 264,197	$ 21,479
Maryland & Virginia CWP	13.90	100,188	$ 390,608	$ 28,101
Maryland & Virginia CWP	11.70	1,019,304	$ 498,808	$ 42,633
Caltrans	4.20	9,148	$ 710,957	$ 169,275

*All costs adjusted to LA region, 1999

Figure 3-13. Wet Pond Costs



15. Wetland

Caltrans construction no stand-along wetland BMPs. Information was obtained, however, for 25 wetland BMP constructed by other entities. This information is summarized in Table 3-18 The median cost per acre treated for this technology was $3,667, ranking second out of 15 BMP technologies.

Table 3-18. Wetland Cost Data

Entity	Drainage Area (acres)	Water Quality Volume (ft³)	Adjusted Total Cost	Adjusted Total Cost per Acre Treated
Maryland & Virginia CWP	611.30	1,032,372	$ 126,182	$ 206
Maryland & Virginia CWP	26.60	148,104	$ 20,178	$ 759
Maryland & Virginia CWP	73.00	69,696	$ 108,029	$ 1,480
Maryland & Virginia CWP	798.30	5,985,144	$ 1,204,859	$ 1,509
Florida DEP	527.00	2,874,960	$ 834,558	$ 1,584
City of Austin	252.00	-	$ 434,310	$ 1,723
Maryland & Virginia CWP	194.00	1,655,280	$ 354,636	$ 1,828
Maryland & Virginia CWP	95.00	326,700	$ 181,014	$ 1,905
Maryland & Virginia CWP	13.10	77,351	$ 30,125	$ 2,300
Florida DEP	2200.00	7,570,728	$ 5,589,195	$ 2,541
Maryland & Virginia CWP	63.10	426,888	$ 222,575	$ 3,527
Maryland & Virginia CWP	29.10	102,366	$ 103,114	$ 3,543
Maryland & Virginia CWP	155.00	622,908	$ 568,371	$ 3,667
Maryland & Virginia CWP	9.30	38,768	$ 36,135	$ 3,886
Olympia	500.00	?	$ 2,161,693	$ 4,323
Maryland & Virginia CWP	47.40	322,344	$ 224,179	$ 4,730
Maryland & Virginia CWP	10.40	156,070	$ 72,383	$ 6,960
MD SHA	24.18	-	$ 179,661	$ 7,430
MD SHA	2.90	15,000	$ 22,969	$ 7,920
Florida DEP	121.00	-	$ 1,302,685	$ 10,766
King County	8.34	unknown	$ 90,331	$ 10,831
King County	6.30	unknown	$ 74,540	$ 11,832
MD SHA	1.20	17,000	$ 14,507	$ 12,089
Florida DEP	9.24	-	$ 127,766	$ 13,827
King County	3.37	6,900	$ 96,776	$ 28,717

IV. RECOMMENDATIONS FOR CONSTRUCTION COST REDUCTIONS

A. Introduction and Summary of Recommendations

This section identifies several options potentially available to limit BMP retrofit construction costs. A summary of these options is as follows:

1. Combine BMP Retrofit Work with Ongoing Construction Projects

Construction costs, including mobilization, are typically higher for individual, small, or isolated projects. Other departments of transportation have reduced retrofit costs by including BMP construction as part of another construction project.

2. Select Low-Cost Technologies

Agencies responsible for storm water treatment across the country are finding a significant difference between the costs for different BMP technologies (see Table 4-1 and Figure 4-1). Assuming adequate treatment efficiency, selection of technologies from the low end of the cost spectrum will result in cost savings. These low cost technologies are often small-scale, shallow controls with vegetated rather than concrete surfaces. They avoid large land acquisition costs, can be located flexibly on an existing site, and do not require extensive concrete or shoring. BMPs with these desirable characteristics include bioswales, biofilter strips, and infiltration trenches.

3. Use Economy of Scale

Some BMP technologies lend themselves to favorable economies of scale for larger projects. Examples include wet ponds and constructed wetlands. Treatment of relatively large areas can offer improved costs per unit of area treated.

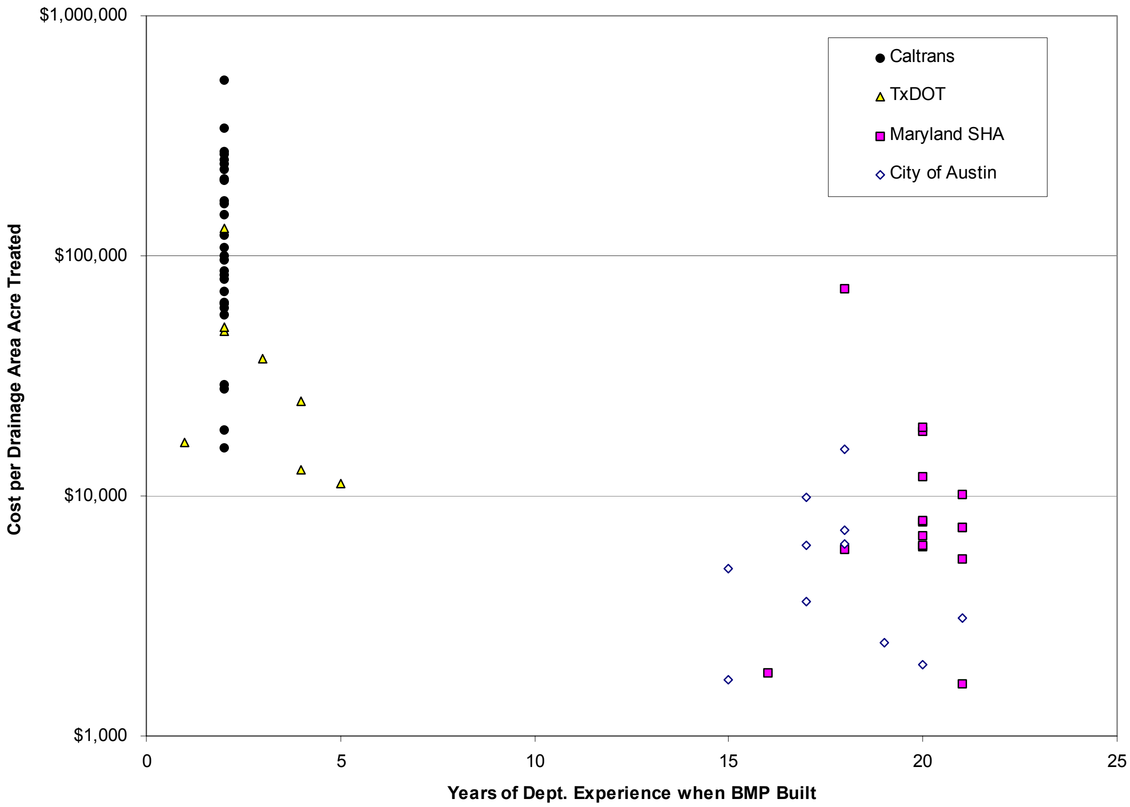
4. Develop Technology Selection Criteria

Technology selection criteria can be developed to specify cost-effective BMPs. These criteria typically include selection criteria based on drainage area size, impervious area size, desired capture depth or design storm size. Criteria can also incorporate information about the available site: size, soil permeability, the depth and usability of underlying groundwater, whether grade is available for gravity flow, and use, utility or buried object constraints.

5. Develop Flexible Design Criteria

Flexible BMP design criteria can be developed. These criteria would allow modifications in required BMP efficiency, capture depth or design storm based on site characteristics.

Figure 4-1 Comparison of Caltrans and Other Agencies BMP Costs



6. Construct Out of the Highway Right-of-Way

Cost savings can sometimes be gained where alternatives exist to building controls within a highway right-of-way. Some potential alternatives include regional cooperation, Water Quality Banking, and piggybacking on new and reconstruction projects.

7. Use Simple BMP Designs

Simple, low maintenance designs reduce both construction and ongoing maintenance costs. These designs typically do not use pumps, valves, complicated piping or plumbing, or filter media that must be frequently replaced.

Each of these options, and others, are discussed in more detail below.

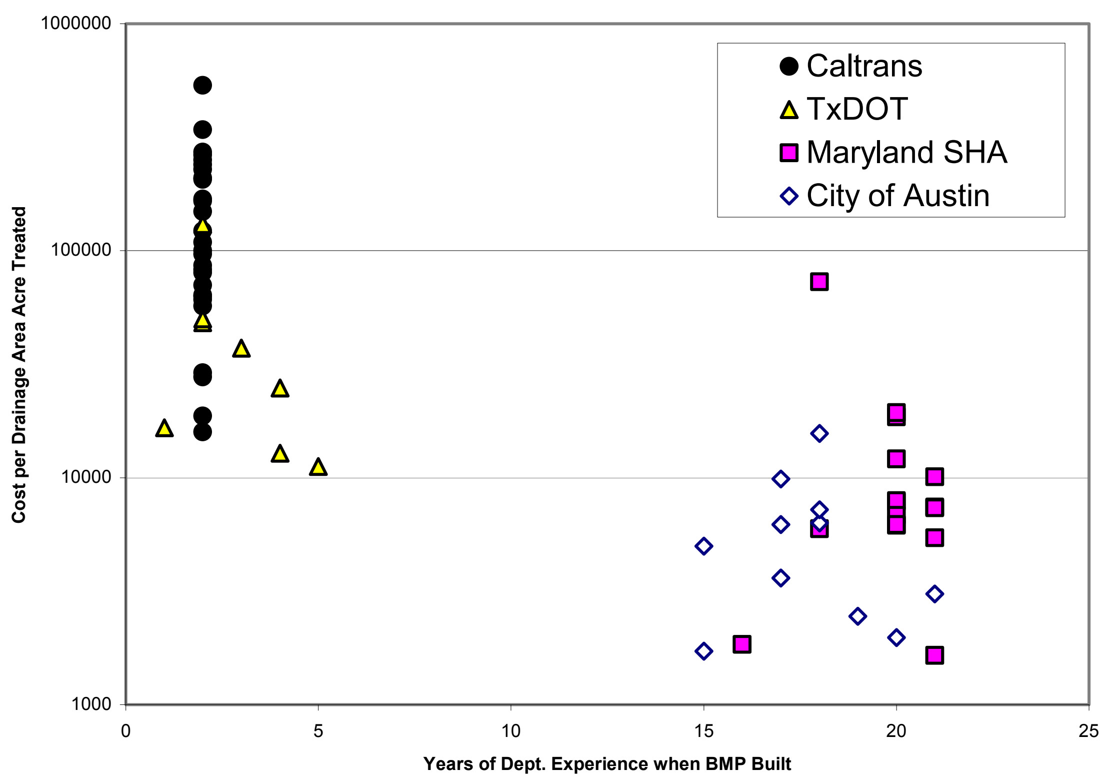
B. Potential Options to Reduce BMP Retrofit Construction Costs

1. Administration

a) Staff Size and Experience of Caltrans Storm Water Program

Based on the experience of transportation departments and other entities, Caltrans can expect cost savings as the department builds its program and storm water staff develops more experience. Interviews with national program managers often identified a five or more year period of program development necessary to become familiar with storm water issues, develop design criteria, and refine treatment technologies suited to their particular geography and climate. Figure 4-1 shows the relationship between the range of BMP costs and number of years of experience based on data collected for this study.

Figure 4-2 BMP Cost per Acre Treated versus Years of Experience



2. Planning

a) Longer Planning Horizon

Future Caltrans BMP design and construction projects can expect cost savings from a longer planning horizon than that allowed for the pilot project. The potential cost benefits of a longer planning horizon are:

- The ability to combine BMP projects with other construction projects. Expected cost reductions would be derived from a more competitive bidding environment, lower costs for mobilization, and lower unit costs from economies of scale on line items like concrete and excavation.
- The ability to schedule work during an optimum time: when competing area uses are at a minimum, when other construction projects will occur, or when landscaping is easiest to establish. For example, required replacement of new highway landscaping for Caltrans' Manchester extended detention basin cost $23,600.

b) Master Planning

(1) Integrated Water Quality, Drainage and Flood Control Systems

An integrated water quality, drainage and flood control system can reduce costs in several ways. In some situations existing drainage and flood control structures can be altered to achieve a retrofit water quality control benefit. Use of these existing structures reduces land, conveyance, inflow and discharge structure costs. Vegetated swales as an alternative to subsurface conduits provide infiltration and pollutant reductions as well as storm water runoff conveyance.

(2) Large-Scaled BMPs

Economies of scale are more significant for expensive technologies and less important on relatively inexpensive technologies like vegetated swales. These economies of scale are realized because costs for several components (conveyance, splitter boxes, and pumps, for example) do not increase proportionally to either the capture volume or discharge rate.

Caltrans pilot BMPs treat runoff from relatively small drainage areas. The largest contributing area was 13.4 acres, the smallest was 0.4 acres and the median size was 1.6 acres. The total drainage served by Caltrans' 33 BMP sites is 81.7 acres. Other transportation entities have constructed one or two regional pond retrofit facilities to serve contributing areas of this size. Existing drainage infrastructure and small, linear drainage areas make these economies of scale particularly challenging to achieve, however, for roadway retrofit BMPs. One option is to plan and construct BMPs that treat runoff from pollutant-generating areas beyond the limits of the roadways. These BMPs would be cost-effective if there were a cost-sharing agreement with the entity responsible for treating the other areas; or with a water quality banking system that would allow Caltrans to avoid constructing one or more additional BMPs to achieve an equivalent pollution reduction. The estimated savings for Caltrans BMP retrofit projects that might be achieved by using large-scaled regional pond controls ranged from 0% to 92% of actual retrofit costs (see Section V and Appendix A).

(3) Small-Scaled BMPs

Some BMP technology types can be cost-effective when built for small drainage areas. Example technologies used in the pilot program include bioswales and biostrips. These vegetative BMPs have relatively low base costs per area treated, are suited to linear highway use for sheet flow and small drainage areas, and have flexible footprints.

These BMPs are often located within medians, tree islands, or other landscaped areas. Since any down-gradient vegetated area is a potential small-scale BMP location, they are particularly cost-effective for roadways, park-and-ride lots, and maintenance stations where they can be placed in close proximity to and threaded through existing uses. Swales, strips and bioretention facilities are easily accommodated within long, linear areas along highways. Where area and gradient is available, these systems can replace concrete channels or conduit conveyance.

Small scale BMPs require less excavation. They have fewer safety requirements because they are not as deep and therefore not as dangerous. When designed and built individually, however, these BMPs may incur relatively high site-specific costs (as a percentage of base cost) for traffic control and mobilization. Mobilization and traffic control costs can be reduced by building a series of these controls collectively, or by combining their construction with roadway repair activities that require lane closures.
The estimated savings for Caltrans BMP retrofit projects that might be achieved by using small-scaled, distributed technologies ranged from 41% to 76% of actual retrofit costs (see Section V and Appendix A).

c) Water Quality Banking

There are a variety of reasons for differences in the cost to achieve a given water quality benefit. These reasons include the size of the contributing drainage area, the availability of suitable areas for conveyance and treatment facilities, the availability of storm water runoff conveyance by gravity flow, site constraints, traffic control requirements, other highway construction contracting and timing factors, and the sensitivity of receiving waters. An approved water quality banking program would reduce BMP retrofit costs by allowing Caltrans to transfer credit for water quality control benefits from areas where costs are low to areas where costs are relatively high.

One measure of the range of cost benefits that could be incurred through a water quality banking program is the range of site specific costs observed for the Caltrans BMP pilot project: $0 to $569,964. The total site specific costs for the BMP pilot project was $3,040,827. [*Note: may want to consider an analysis similar to that presented for Sharing of Costs in Appendix A.*]

d) Regional Partnerships/Cost Sharing

Highways generally drain from small contributing watersheds to areas where runoff commingles with non-highway runoff en route to receiving waters. BMPs restricted to highway ROW locations typically treat only runoff from these small watersheds. Cost-effective designs featuring larger contributing areas, use of park or flood control sites, and low-impact-design principles are not typically available to BMPs limited to treating only highway runoff.

Achieving the value of these cost-effective designs would require Caltrans to form partnerships with other entities responsible for storm water BMPs. Through partnering, Caltrans might save costs by increasing their options in both the siting and the types of BMPs. Partnerships might undertake BMP design, construction, and/or operations and maintenance. Based on the pilot project costs, savings to Caltrans from a partnering arrangement might be within the following ranges:

Avoiding site constraints:	\$0 to \$569,964 (each site) \$0 to \$3,199,943 (all sites)
Increase in contributing area (See Section V for calculations and assumptions):	\$0 to \$6,732,695
Avoiding traffic control costs:	\$0 to \$59,496 (each site) \$0 to \$403,534 (all sites)

Other benefits that could be derived from partnerships for which costs are not estimated include creation of multi-use facilities with recreation, flood, and erosion control benefits or habitat restoration projects, such as the creation of wetlands.

3. Design

a) Technology Selection Criteria

Technology selection criteria can be developed to guide the design of cost-effective BMPs. These criteria typically include selection criteria based on drainage area size, impervious area size, and desired capture depth or design storm size. Criteria can also incorporate information about the available site: site size; soil permeability; the depth and usability of underlying groundwater; whether grade is available for gravity flow; and use, utility or buried object constraints. Additional criteria regarding the level of treatment or effectiveness standard to be achieved must also be incorporated. The estimated savings for Caltrans pilot BMP retrofit projects that might be achieved by using less expensive technologies, ranged from 41% to 76% of actual retrofit costs (see Section V and Appendix A).

b) Capture Volume

Water quality capture volume affects BMP cost, pollutant removal efficiency and the mass of pollutants removed. As the volume increases, BMP cost and the mass of pollutants removed also increases. Because pollutant concentrations are sometimes highest in the runoff just after a rainfall begins, however, pollutant removal efficiency often decreases within increasing size. No analysis of the optimum capture volume for a particular water quality control, therefore, can be made without considering the pollutant removal standard.

Nevertheless, in general a smaller capture volume provides two cost benefits. One benefit is that the amount of land, construction materials, and construction labor cost is less. Another benefit is that, because the control is shallower or occupies a smaller area, constraints that significantly increase costs for a larger control can be reduced or avoided all together. Costs at Altadena Maintenance Station in Los Angeles, for example, for shoring and concrete, replacing pavement destroyed by heavy equipment for shoring, and moving/reconstructing storage bins might have been avoided by reducing the required capture volume.

By following the lead of many other storm water quality management agencies around the country and establishing either a smaller capture volume or a flexible capture volume policy, Caltrans might avoid the following costs, based on the pilot retrofit projects:

Avoiding site constraints:	\$0 to \$569,964 (each site) \$0 to \$3,199,943 (all sites)
Increase in contributing area (See Section V for calculations and assumptions):	\$0 to \$6,732,695

c) Design

(1) Facility depth

Several construction operations and maintenance costs accrue to facilities that are deeper than 6 to 10 feet. These costs include more expensive excavation, shoring, ladders, safety fencing, and concrete, and a higher probability of interference from buried objects. Maintenance of deep BMPs requires added costs and concerns for enclosed space safety.

Facility depth is a function of both the capture volume and the area available for the control. Certain BMP technologies are inherently shallow: swales, filter strips, bioretention, infiltration devices. Some example pilot project costs that might have been reduced or eliminated by using shallow BMP technology are shown in Table 4-1.

Table 4-1. Example Line Item Costs Associated with Facility Depth

Retrofit Pilot Project			Element	Cost
111102	EDB	I-15/SR 78	Buried Objects	\$439,091
112204	MFSA	SR 78/I-5 Park & Ride	Shoring	\$ 26,887
112203	MFSA	La Costa Park & Ride	Shoring	\$ 15,744
074202	MFSA	Eastern Regional Maintenance Station	Shoring	\$ 77,640
074203	MFSA	Foothill Maintenance Station	Shoring	\$ 98,955
074204	MFSA	Termination Park & Ride	Shoring	\$ 91,132
074206	MCTT	Via Verde Park & Ride	Shoring	\$ 66,664
074208	MCTT	Lakewood Park & Ride	Shoring	\$ 85,150
112204	MFSA	SR 78/I-5 Park & Ride	Utility Conflicts	\$ 4,100
112207a	BSTRP	Carlsbad Maintenance Station (west)	Utility Conflicts	\$ 3,334
073222a	BSTRP	I-605/SR 91	Utility Conflicts	\$ 8,111

Retrofit Pilot Project			Element	Cost
073223	BSW	Cerritos Maintenance Station	Limited Head (Pumping)	$ 3,721
074202	MFSA	Eastern Regional Maintenance Station	Limited Head (Pumping)	$ 22,525
074204	MFSA	Termination Park & Ride	Limited Head (Pumping)	$ 19,926
112203	MFSA	La Costa Park & Ride	Buried Objects	$ 31,930
111103	IB	I-5/La Costa (west)	Buried Objects	$ 26,932
112204	MFSA	SR 78/I-5 Park & Ride	Safety Security (fences, guardrail)	$ 13,984
112203	MFSA	La Costa Park & Ride	Safety Security (fences, guardrail)	$ 13,724
074204	MFSA	Termination Park & Ride	Safety Security (fences, guardrail)	$ 6,403

(2) Site footprint

BMPs with larger facility footprints are generally more difficult to locate on the site. Higher costs and a lack of functionality often result. Large footprints for some Caltrans pilot BMPs, for example, displaced site functions and required those uses to be demolished and reconstructed. BMPs also resulted in a loss of park-and-ride parking spaces with attendant cost and inconvenience. Constructing BMPs with smaller footprints by reducing the design storm treated, reducing the capture volume, or increasing the depth optimizes flexibility. Each of the choices also has potential disadvantages, as discussed in other sections.

Vegetated and bioretention BMPs are particularly useful for application in small units because of their lower unit costs

Examples of pilot project retrofit costs that might have been saved by reducing the site footprint are shown in Table 4-2.

Table 4-2. Example Line Item Costs Associate with Site Footprint

Retrofit Pilot Project			Element	Cost
073211a	BSTRP	Altadena Maintenance Station	Facility Restoration and Utility Conflicts	$ 24,407
111105	EDB	I-5/Manchester (east)	Facility Restoration	$ 23,587
074203	MFSA	Foothill Maintenance Station	Facility Restoration	$ 47,862
111104	WB	I-5/La Costa (east)	Site Clearing, Grubbing & Removals	$ 70,890
073101	IB	I-605/SR 91	Site Clearing, Grubbing & Removals	$ 44,615
074203	MFSA	Foothill Maintenance Station	Site Clearing, Grubbing & Removals	$ 64,887
112206	BSW	I-5/Palomar Airport Rd	Utility Conflicts	$ 5,000
074202	MFSA	Eastern Regional Maintenance Station	Utility Conflicts	$ 18,394
074204	MFSA	Termination Park & Ride	Utility Conflicts	$ 11,889

Where maintaining site functionality is of the highest priority, subsurface BMPs are appropriate.

(3) Inflow/outflow structures, piping

Inflow and outflow structures represent an estimated 0 to 8.5% of all pilot retrofit construction costs. These costs might be lowered or eliminated for future BMPs because:

- Future BMPs will not be constrained by the requirement to collect representative samples and monitor all influent storm runoff.
- Caltrans might design structures to discharge directly into existing offsite storm sewers. Offsite storm sewers are deeper, and often significantly deeper than onsite storm conveyance systems. Pilot BMPs incurred pump and piping costs to convey effluent back to the onsite storm conveyance system.
- Some BMPs have more complex inflow and outflow than others: choose those which are simpler.
- Inflow and outflow structures can be constructed using rock riprap where possible in place of concrete for spillways and inflow energy dissipaters.

(4) Pumps versus gravity flow

Several of the Caltrans pilot retrofit BMPs required pumps for storm water runoff conveyance. There were two reasons for this requirement for the pilot project. One reason was the desire by Caltrans to discharge BMP effluent into the same storm system from which storm water was conveyed into the treatment facility. A policy decision was made not to investigate the possibilities of offsite discharge into deeper storm sewers to which effluent might have been conveyed by gravity flow. The other reason for pump conveyance was the desire to convey effluent to a convenient location for monitoring.

Pumps contribute significantly to BMP construction, operations, and maintenance costs. Compared to other BMP system components they are unreliable and prone to failure. Good BMP design relies as much as possible, upon conveyance by gravity flow. Whether runoff treatment is achievable with gravity conveyance depends on the treatment technology, and the elevation difference between influent storm water and a reasonably available discharge location.

(5) Safety features

Three safety goals must be achieved for all BMP construction, operation, and maintenance:

1. Safe, smooth and efficient traffic flow on roadways in the vicinity of the BMP;
2. Adequate protection for all staff responsible for constructing, inspecting, operating, or maintaining the BMP; and
3. Safety for any public in close contact with the BMP during construction, operation, and maintenance.

Factors that affect these safety goals are the proximity of the BMP to the roadway, the presence or absence of adequate construction staging locations, the facility depth and slope, and fencing. Options to improve safety and/or lower associated costs include:

- Using regional BMPs to get facilities off of the highway ROW;
- Using Water Quality Banking to treat water in favorable areas, possibly as part of overtreating a new highway or in a redevelopment project. These projects would either not require or would already have traffic controls, thereby incurring no extra costs for the retrofit BMPs;
- Constructing BMPs while adjacent roadways or lanes are closed for non-BMP highway construction and/or maintenance;
- Using one traffic control system to construct a series of BMPs along one stretch of highway; and
- Building BMPs no more than 6 feet deep and providing basin side slopes no steeper than 3:1 (run:rise). Basins with side slopes no steeper than 3:1 do not require fencing (City of Austin Environmental Criteria Manual).

(6) Component and Materials Selection/Standardization

Other storm water management entities have, through experience, significantly reduced BMP construction and maintenance costs. Options available to Caltrans include:

- Finding low-cost, locally available components. The sand specified in the Austin sand filters built in the Los Angeles pilots, for example, was a special gradation available from only one supplier in southern California. This increased the cost of this component of the construction. TxDOT reported significant cost reductions over time as they located and selected locally available parts and materials (Nyland, 2001). These items were generally also simple and straightforward to obtain and install, as well as economical.

- Optimizing components and materials selection. Seed is less expensive than sod and suitable for many BMP applications, particularly when revegetation is timed for optimum growth. Local rock and plant material can often be used in place of imported material.
- Standardizing BMP construction elements. Significant differences exist, for example, between Delaware's reported cost for the precast Delaware sand filter and Caltrans cast-in-place filter. If Caltrans continues to use the Delaware sand filter, they might work with local precast concrete companies to supply the vaults for routine installation. Were Delaware costs to be achieved by Caltrans through standardization of components and familiarity with the technology, a BMP serving a drainage area the same size as that of the Escondido BMP would cost approximately $66,500 (adjusted for Los Angeles region)—about 13% of the pilot cost.

(7) Concrete versus earthen construction

Caltrans pilot BMPs used concrete in their construction, where many other entities chose earthen, rock or vegetated BMP surfaces. Earthen, rock, or vegetated surfaces are less expensive, and contribute to pollutant adsorption, filtration, and infiltration, where concrete does not. Earthen construction would not necessarily require the heavy equipment, forms, and space that are required to construct massive concrete structures.

Concrete construction is often necessary when small areas require steep or vertical walls and deep controls. Caltrans would not be able to take advantage of the benefits of earthen construction without implementing some of their other alternatives to construct BMPs that are shallower and/or have large sites.

(8) Maintenance Features & Access Roads

Caltrans pilot BMPs featured paved access roads for maintenance and vector control access. Adequate operation and maintenance access is a critical component of BMP design and Caltrans is to be commended for recognizing the importance of adequate access in their designs. Where access roads completely surrounded the BMP, however, the length and cost of maintenance access is greater than is required or constructed by other entities. The City of Austin, for example, requires access drives to be cleared, graded and stabilized with stone. Only the point of access is paved with a concrete driveway entrance. Access drives must by at least 12 feet wide, not more than 15% grade, and include a means for equipment to turn around. Basins are typically designed with access into the bottom of the basin, rather than access around the top. Another option to reduce the need for access roads completely surrounding the BMP would be to provide a sediment forebay at the basin inlet. The forebay focuses routine maintenance at one location within the basin and reduces the need to maintain other areas.

Assuming that a 50% reduction in access road costs is achievable, the estimated savings range from $0 to $112,670.

d) Additional site and geotechnical investigation

Costs incurred for several Caltrans pilot facilities were due to site conditions that were not identified until after construction began. These conditions included large buried objects, high groundwater conditions, unexpected soil permeability, and site utility and use constraints. The rapid time frame for completion of the pilot BMP design and construction program makes failure to identify these conditions prior to design completion more likely than for a normal program of BMP implementation. With adequate site and geotechnical investigations, Caltrans can expect to reduce costs due to buried objects to a more normal 1.4% (District 7 in the 1999 calendar year; Doug Failing, 2001) of the total construction cost, compared to 5.6% for the pilot retrofit BMPs. Where preliminary site investigations indicate a condition as expensive as removing a buried bridge, Caltrans could implement a policy to explore alternative sites, or alternative methods, like water quality banking, for meeting their pollution reduction goal.

4. Bidding and Contracting

Several factors affect the profitability, risk, and competitiveness of bidding for a construction contract. These factors include:

- the availability of other construction work;
- the size of the job;
- the structure and clarity of the bid package; and
- the number of contractors with experience, equipment, labor, and bonding ability to perform the work.

While there is little that Caltrans can do directly to influence the balance between construction contractor supply and demand, there are several things that Caltrans might do to make BMP construction contracts as desirable, and therefore as competitive, as possible, including:

- Adjusting the size of construction bid packages by including more than one BMP. The bidding will be most competitive when the contract is large enough to generate an attractive profit, but not so large that smaller contractors cannot meet bonding requirements.
- Working with contractors to make sure that all construction and bid documents are clear and designed to achieve a low-cost bid. Large lump sums might be broken out into particular component bid items.
- Providing adequate field supervision of construction contractors.
- Allowing adequate time for a standard competitive bid process, for contract negotiation and for construction. This will limit costs associated with a procurement process, contract change orders, force accounts, or overtime charges.
- Pulling bids back that greatly exceed the Engineer's Estimates and reworking them and/or delay them until a more advantageous future time.

- Combining BMP construction with other roadway construction projects. Maryland and TxDOT use this contract structure almost exclusively for BMP construction. There are several advantages. One advantage is that the contractor may already be mobilized with staff, equipment, and materials near the BMP site. Administrative and management costs can be reduced. The largest cost savings, however, may be that the profitability of the familiar roadway construction project can mitigate the problems associated with a smaller, unfamiliar, and more risky BMP construction project.

Storm water managers for other entities report lower BMP construction costs as contractors develop additional experience. The difference in contractor experience may, therefore, explain some of the lower costs for similar BMP construction in communities where a larger number of BMPs have been installed over a longer period of time.

V. CONSTRUCTION COSTS OF FUTURE BMP DEPLOYMENT

A. Introduction

B. Small-Scaled BMP Implementation: Distributed BMPs

National data were reviewed to develop a cost per acre treated figure for the use of distributed BMPs. Biofilter strips, infiltration trenches, and bioswales were all considered. The cost data reviewed included the following items:

Distributed Control Type	Reported Cost per Acre Treated*	Cost Rounded up to Nearest $500*	Source and Type of Data
Biofilter Strip	$0	$0	Maryland State Highway Administration: integrated controls: no additional cost.
	$4,698	$5,000	Oregon DOT maximum (range = $4,510 to $4,698).
Infiltration Trench	$5,505	$6,000	Maryland State Highway Administration median value.
	$10,484	$10,500	Florida Dept. of Environmental Protection.
	$11,745	$12,000	National median cost/acre (from Section III).
	$13,155	$13,500	Oregon DOT maximum (range = $3,417 to $13,155).
Bioswale	$0	$0	Maryland State Highway Administration & Virginia DOT: integrated controls—no additional cost.
	$6,875	$7,000	Washington State DOT: $10,000 per lane mile (assume 12 ft. lanes). Cost includes compost soil amendment. Approx. ½ cost without compost.
	$10,000	$10,000	Massachusetts DOT: $8-10,000 for 1 acre drainage area.
	$12,289	$12,500	National median cost/acre (from Section III).
	$18,793	$19,000	Oregon DOT maximum (range = $2,506 to $18,793).
	$35,672	$36,000	ODOT single project (drainage area = 1.2 acres) with high value of all distributed BMP costs available.
Lower Distributed Control Cost		**$19,000**	**Low cost used in analysis.**
Higher Distributed Control Cost		**$36,000**	**High cost used in analysis.**

* All costs adjusted using Means® Localization Factors to approximate those of Los Angeles.

The highest cost from this available data is $36,000 per acre treated. This value was chosen as a "high" value for the present cost analysis. A second value of $19,000 per acre treated was also examined as a "low" cost analysis. It is actually one of the higher values among the data available but was chosen as a relatively conservative "low" value. For each of the 39 pilot BMPs evaluated at 33 different sites, potential costs to construct small-scaled, distributed vegetated and infiltration BMPs in place of the constructed technology were calculated. Estimated Distributed BMP costs were derived for each site by multiplying the Acres of Site Drainage Area times $19,000 and $36,000 per acre respectively for all pilot BMP applications, including those which used biofilter practices. The total cost for all sites was summed to yield high and low estimates for implementing such a strategy throughout an area comparable in size to the 33 site area. The resulting total costs (rounded to nearest $1000) were as follows:

Caltrans Pilot BMPs

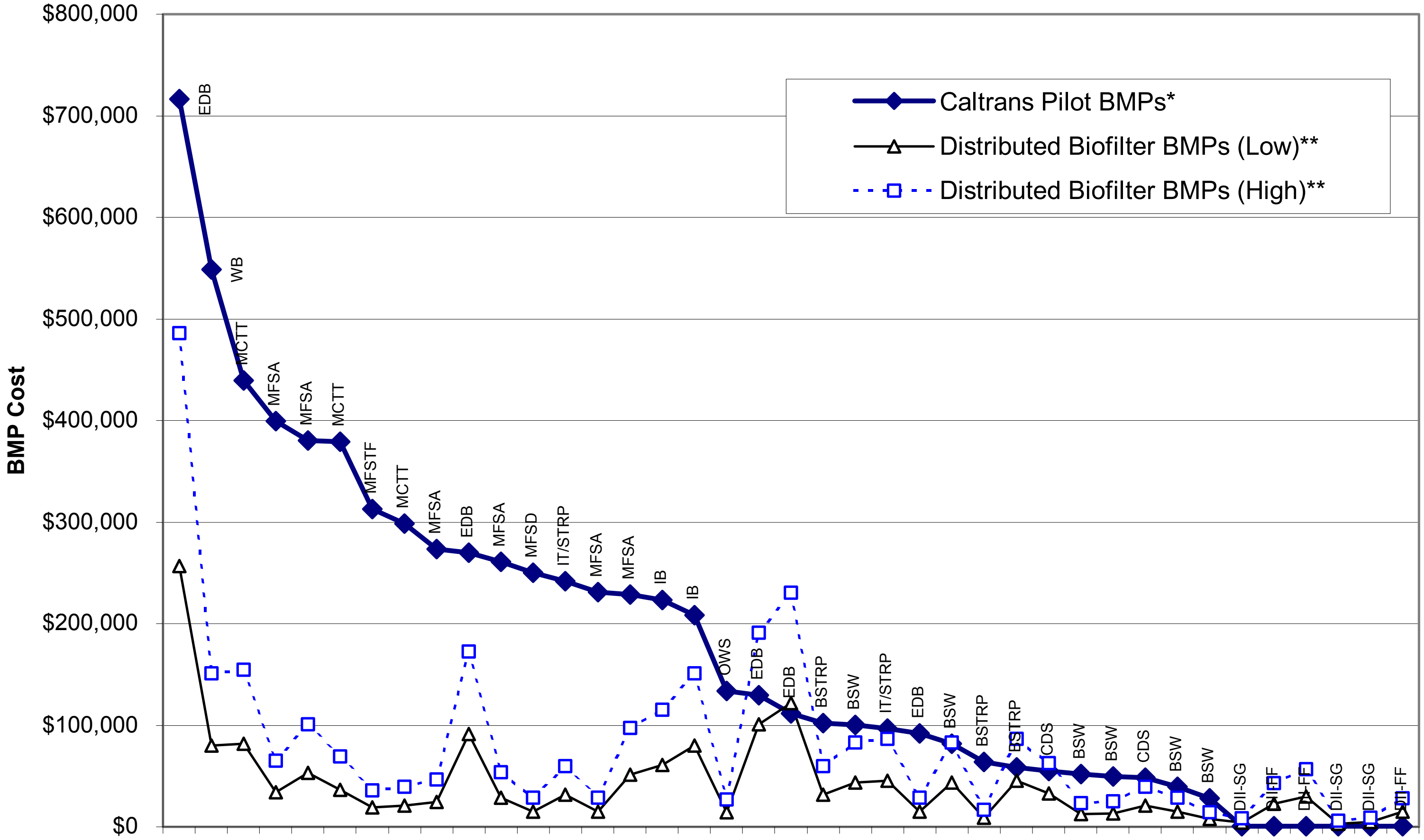
$ 6,906,000		Total Actual Pilot Program Cost (Base Cost plus Site-Specific Cost)

Distributed BMP Costs

High	Low	
$ 3,095,000	$ 1,633,000	Estimated Cost for Same Sites using Distributed Practices
$ 3,811,000	$ 5,273,000	Estimated Savings for same sites using Distributed Practices
55%	76%	Resulting Potential Cost Reduction for Distributed Practices compared with Pilot BMPs

Figure 5-1 shows a comparison between actual pilot costs (excluding pilot unique costs) with those for sites with the same drainage area size using the high and low scenario biofilter practices at national costs. The figure indicates the original technology type of each of the sites. The figure shows that for the "low" scenario, with the exception of one extended detention basin site and the drain inlet insert sites, the cost for implementing distributed controls is lower than for the pilot BMP technology selected. For the "high" cost scenario, the distributed practices were lower in cost except for the six drain inlet sites and five other sites (two extended detention sites, a bioswale site, a biofitlter strip site, and a CDS site).

Figure 5-1. Comparison of Actual Pilot Costs with Potential Costs Using Small-Scaled, Distributed Biofilter and Infiltration BMPs



* Base Cost + Site Specific Cost; Pilot Unique Costs not included.
** Based on ODOT bioswale cost per acre treated adjusted to Los Angeles region. Represents the maximum distributed BMP cost among national data available for bioswales, biofilter strips, and infiltration trenches.

C. Large-Scaled BMP Implementation: Pond BMPs

An analysis was performed to calculate the cost of implementing large-scaled pond BMPs. Large-scaled BMPs have the potential to offer more cost-effective treatment on a per unit treated basis. The following inputs and assumptions were used:

81.9	Total drainage area of all Caltrans pilot BMPs
85	Drainage area rounded up to nearest 5 acres.
$7,285,195	Base Cost + Site Specific Cost for all Pilot BMPs constructed
1	Inches captured over DA
308,550	Water Quality Capture Volume required (cubic feet)
5	Assumed average pond depth (feet)
61,710	Pond pool footprint (square feet)
1.42	Pond pool footprint (acres)
20%	extra land needed for buffer around pond
1.7	Land needed for pond site or sites (acres)*
$6,500	Median National Cost for Wet Ponds per acre treated (see Sec. III) rounded up to nearest $500

* Note: This analysis could reflect 1 pond of 1.7 acres or 2 ponds of 0.9 acres, etc., so long as scale is that of larger pond facilities.

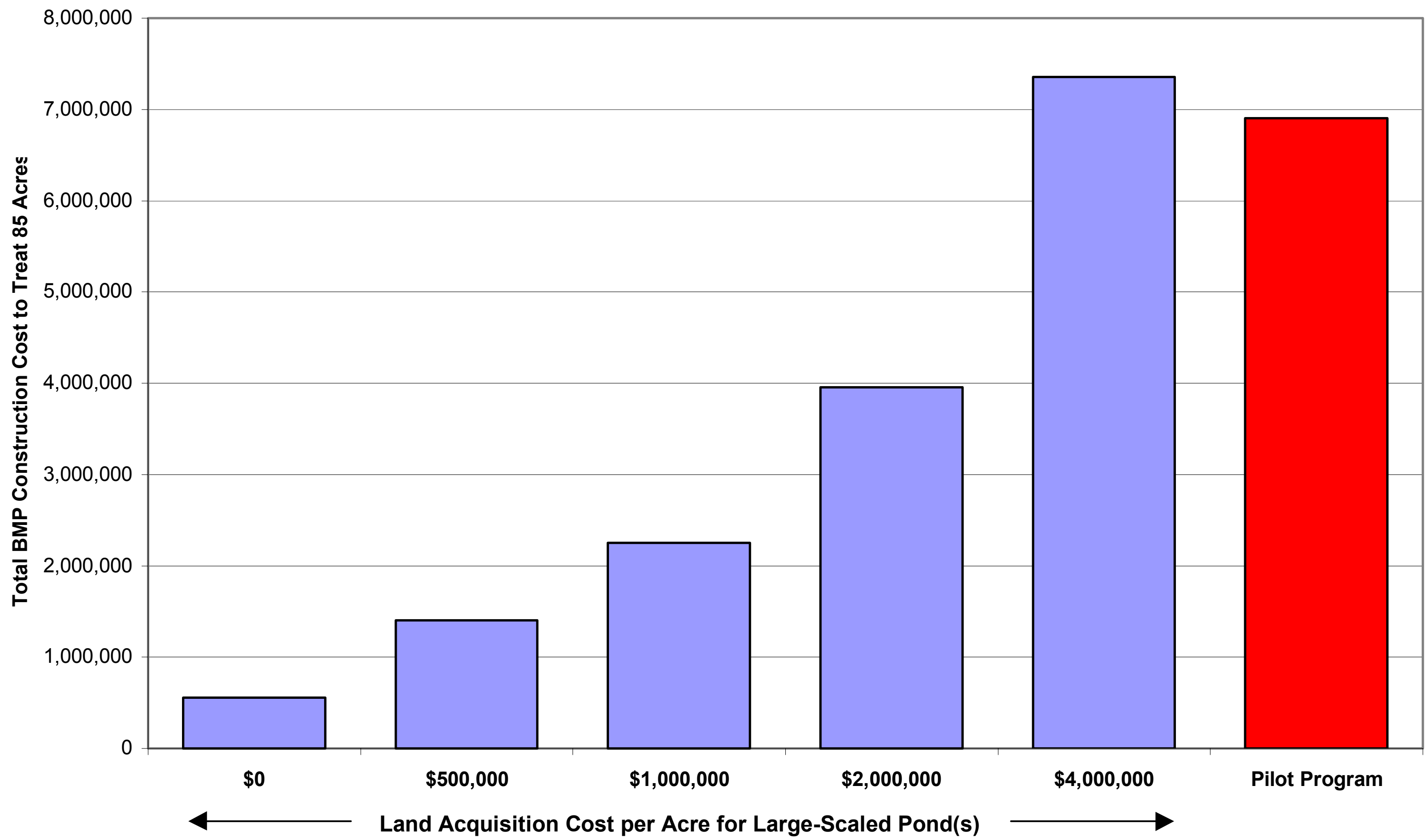
The product of 85 acres times $6,500 per acre treated equals $552,500. This would be the theoretical cost of a wet pond facility serving 85 acres in Los Angeles *assuming no land acquisition costs*. Scenarios adding land costs at a variety of cost levels for the 1.70 acres of land needed were also considered as follows:

Land Acquisition Cost for Pond Easement ($/acre)	Estimated Large-Scaled Wet Pond Cost	Savings Compared with Pilot Program Cost*	Pct. Pond Cost of Pilot Program Cost*
1. $ 0	$ 552,500	$6,353,342	8%
2. $ 100,000	$ 722,500	$6,183,342	10%
3. $ 250,000	$ 977,500	$5,928,342	14%
4. $ 500,000	$1,402,500	$5,503,342	20%
5. $1,000,000	$2,252,500	$4,653,342	33%
6. $2,000,000	$3,952,500	$2,953,342	57%
7. $3,000,000	$5,652,500	$1,253,342	82%
8. $4,000,000	$7,352,500	$ (446,658)	106%

* Pilot program cost = $7,285,195 for 39 BMP applications at 33 sites (excludes pilot unique costs).

Figure 5-2 depicts the comparison between actual pilot costs (excluding pilot unique costs) with those of the scenarios for large-scaled ponds with varying land costs. The figure and the table above indicate that cost to build a large-scaled pond for an area treating the combined area of the pilot retrofits will be lower than those of the pilot study unless the cost of land acquisition approaches $4,000,000 per acre.

Figure 5-2. Comparison of Actual Pilot Costs with Potential Costs Using Large-Scale Pond BMPs for a Range of Land Acquisition Costs



Appendix A: Description of Glenrose Engineering's Pilot Unique Calculations

The following section describes the methods used to calculate potential pilot unique portions of the total construction cost for the pilot program. Table A-1 provides a summary for the findings of this section.

1. Monitoring-Related Costs

a) *Sampling Equipment* .... *Same as H&N evaluation.*

b) *Associated Structures*

Pilot Unique Table Text: Diversion junction boxes, pavement work, piping, manholes, minor and miscellaneous concrete associated with directing flows to monitoring equipment and with diverting non-monitored flows around BMP would be unnecessary for unmonitored sites.

Have not yet fully evaluated.

c) *Power Supply* .... *Same as H&N evaluation.*

d) *Higher Cost BMP Components* .... *Same as H&N evaluation.*

e) *Protection/ Security Facilities* .... *Same as H&N evaluation.*

f) *Site Access* .... *Same as H&N evaluation.*

2. Consent Decree/ Stipulation Requirements & Pilot Site Selection Artificialities

a) Accelerated Time of Completion

Pilot Unique Table Text: Pilot project timeline forced a variety of unusual costs not applicable to non-Pilot projects with more flexible timelines. Examples include the use of sod vs. seed at multiple sites, use of Force Account and overtime work to meet deadlines, Construction Change Order after bid rather than Addendum, etc.

Pilot unique *Accelerated Time of Completion* costs in addition to those assigned by H&N were calculated by discounting Force Account line items in the breakdown.xls spreadsheet by 15%. Using this method, a preliminary estimate of the possible pilot unique markup for Force Account work was $84,991 (the largest portion of which occurred during the I-15/SR-78 bridge removal work, done with Force Account and overtime work). Thus an upper pilot unique range of 3.0% of total construction cost for *Accelerated Time of Completion* was added to the lower range of 2.1% as shown in Table A-1. No precise assessment of the actual markup, if any, as a result of the use of Force Account work can be known; the 15% assumed for this analysis represents a reasonable figure based upon engineering judgement to establish a range of potential pilot unique costs for this factor.

Table A-1 Range of Pilot Unique Costs Incurred in Pilot Retrofit Study

	Category		Pilot Unique Subcategory		Type	Program Total		% Total Program Actual Const. Cost		Rank	
						High	Low	High	Low	High	Low
1.	**Monitoring-Related Costs**	a.	Sampling & Monitoring Equipment	Sampling Equipment	Pilot Unique	$ 71,827	$ 71,827	0.8%	0.8%	8	10
		b.	Structure associated with monitoring	Associated Structures	Pilot Unique	Under Review	$ 522,358		5.8%		2
		c.	Power Supply Requirements	Power Supply	Pilot Unique	$ 207,370	$ 207,370	2.3%	2.3%	6	4
		d.	Higher Cost Components for Monitoring	Higher Cost BMP Components	Pilot Unique	$ 82,748	$ 82,748	0.9%	0.9%	7	9
		e.	Protection/Security Facilities	Protection/ Security Facilities	Pilot Unique	$ 52,170	$ 52,170	0.6%	0.6%	9	11
		f.	Site Access for Monitoring Activities	Site Access	Pilot Unique	$ 17,542	$ 17,542	0.2%	0.2%	12	14
2.	**Consent Decree/ Stipulation Requirements & Pilot Site Selection Artificialities**	a.	Accelerated Time of Completion	Accelerated Time of Completion	Pilot Unique	$ 269,508	$ 184,517	3.0%	2.1%	5	6
		b.	BMP/Site Selection Artificialities	Site Selection Artificialities	Pilot Unique	$ 3,686,215	$ 0	41.0%	0.0%	2	16
		c.	Sharing of Construction Costs	Sharing of Costs	Pilot Unique	$ 1,798,153	$ 0	20.0%	0.0%	4	16
		d.	Scoping/Siting Study Limitations	Scoping/Siting Study Limited to Caltrans ROW	Pilot Unique	*See "Size of BMPs"*					
3.	**Non-BMP Retrofit Costs**	a.	Maintenance Station Remodeling Costs	Additional Storage Bins	Ancillary	Under Review	$ 0		0.0%		16
4.	**Contracting Method**	a.	Competitive Bidding Environment	Lack of Competetive Bid	Pilot Unique	$ 2,337,599	$ 358,793	26.0%	4.0%	3	3
5.	**Experience of Designers**	a.	Use of Standardized vs. Custom BMP Designs	Standard Designs	Pilot Unique	Under Review	$ 0		0.0%		16
		b.	Unfamiliarity with Site-Specific BMP Designs	Site Specific Designs	Pilot Unique	Under Review	$ 100,764		1.1%		8
		c.	Use of Overdesigned Features	Overdesigned Features	Pilot Unique	Under Review	$ 157,064		1.7%		7
		d.	Unfamiliarity with Vector Control Issues	Vector Control Issues	Pilot Unique	$ 14,100	$ 14,100	0.2%	0.2%	13	15
6.	**Experience of Construction Contractors**	a.	Unfamiliarity with BMP Construction	Construction Contractors Experience	Pilot Unique	*See "Lack of Compe-tetive Bid"*	$ 549,645		6.1%		1
7.	**Costs for Non-BMP Items**	a.	Culvert Cleaning, Infrastructure Maintenance	Clear Blocked Storm Drains	Ancillary	$ 35,958	$ 35,958	0.4%	0.4%	11	13
		b.	Traffic Control	Traffic Safety	Ancillary	$ 44,263	$ 44,263	0.5%	0.5%	10	12
8.	**Quantity of BMP Pilots**	a.	Field Crew Utilization	Quantity of BMPs	Pilot Unique	*See "Sharing of Costs"*					
		b.	Material Costs	Higher Cost BMP Components		*See "Lack of Competetive Bid" [?]*					
9.	**Size of BMP Pilots**	a.	Fixed Construction Costs	Size of BMPs	Pilot Unique	$ 8,271,506	$ 0	92.0%	0.0%	1	16
		b.	Equipment Costs							#N/A	16
		c.	Material Costs							#N/A	16
10.	**Nature of Retrofit Construction**	a.	Demolition of Existing Facilities	Facility Restoration	Site-Specific	*See "Sharing of Costs"*	$ 207,088		2.3%		5
11.	**Vegetation for Biofilters**	a.	Sod, Flats, Plugs, Seeds	Accelerated Time of Completion	Pilot Unique	*See "Accelerated Time of Completion"*					
12.	**Bid Procedures**	a.	Unecessary Bid Items	Lack of Competetive Bid	Pilot Unique	*See "Lack of Competetive Bid"*					

Note: A full *Accelerated Time of Completion* accounting was not possible for the pilot costs. Many costs, such as the relatively accelerated process of site selection and engineering design may have led to higher costs than would have a more normally paced process. Some of these potential added costs may be accounted for in other sections such as *Site Selection Artificialities* and *Scoping/Siting Study Limited to Caltrans ROW*.

b) Site Selection Artificialities

Pilot Unique Table Text: Constrained site selection, size forced some BMPs to be constructed on sites inappropriate to the technology selected. Costs avoided if best BMP for site selected (e.g., extensive shoring used in LA Sand Filters and MCTTs).

An analysis was conducted to determine the potential cost that might have been incurred were bioswales and biofilter strips considered for *all* sites, not just those stipulated under the terms of the pilot program. The small relative size of the drainage areas of the pilot sites (maximum drainage area of 13.4 acres, median size of 1.7 acres) featuring sheet flow from highway and parking lot is the type of situation where distributed vegetated controls are cost-effective compared to other technologies.

The following table presents actual pilot retrofit costs to construct biofilter strips and bioswales:

WQ ID No.	Type	Site Location	Base Cost + Site Specific Caltrans Cost per Acre Drainage Area
112207a	BSTRP	Carlsbad Maint. Station (west)	$ 24,276
073211a	BSTRP	Altadena Maint. Station	$ 61,677
073222a	BSTRP	I-605/SR 91	$ 135,635
112205	BSW	SR 78/Melrose Dr.	$ 35,445
112206	BSW	I-5/Palomar Airport Rd.	$ 44,525
073222b	BSW	I-605/SR 91	$ 41,914
073223	BSW	Cerritos Maint. Station	$ 70,852
073224	BSW	I-5/I-605	$ 79,713
073225	BSW	I-605/Del Amo Ave.	$ 70,528
Median Value			$ 61,677
Round up to Nearest $500			**$ 62,000**

Potential costs to construct distributed vegetated BMPs in place of the constructed technology were calculated for all pilot BMP locations. Estimated Distributed BMP costs were derived for each site by multiplying the Acres of Site Drainage Area times $62,000 per acre for all pilot BMP applications which did not use biofilter practices. For those sites which used biofilter practices (swales and filter strips), actual pilot costs were assumed. If the Estimated distributed BMP cost was greater than that of the actual pilot BMP (Base Cost plus Site-Specific Cost—Pilot Unique costs were not included), then the lower pilot cost was accepted. Where a distributed BMP cost was lower, this was accepted. This roughly approximated the practice of selecting a lowest cost technology wherever possible. The total of all sites was thus summed to yield an estimate of the cost of implementing such a strategy throughout the 33 site area.

The resulting total cost was calculated as follows:

$ 6,906,000	Total Actual Pilot Program Cost (Base Cost plus Site-Specific Cost)
$ 4,057,000	*Estimated Cost for same sites using Distributed Practices or original pilot BMP selection (whichever is lower)*
41%	Resulting cost reduction

Thus an upper pilot unique range of 41% of total construction cost for *Site Selection Artificialities* was established as shown in Table A-1.

c) Sharing of Costs

Pilot Unique Table Text: Costs associated with retrofit construction (such as Mobilization, Grading, Excavation, Clearing & Grubbing, and modifications to the existing drainage network) may be reduced if the BMP were constructed as a component of an integrated Caltrans construction-retrofit project or as a component of a new construction project (e.g. widening existing bridge, adding lanes, adding interchange, etc) where existing drainage facilities are being rebuilt.

The H&N Site-Specific cost spreadsheets were developed in part to address site-specific issues possibly unique to pilot projects. The Site-Specific Cost categories include some cost items which could be either reduced or eliminated were future BMPs to be built as integrated components in new construction or reconstruction projects. The following table shows the Site-Specific items which may be reduced in combination with a larger project. Those which are less certain to have such impacts were not included:

Original Site-Specific Costs by H&N	**Original Pct. of Total***	**Possible Reduction in Combo Project?**	**Pilot Unique Pct. of Total**	Comments
Inlet/Outlet Drainage Systems	8.5%	Yes	8.5%	Can design inflow/outflow with rest of system.
Access Roads (Vector Control/ Maintenance)	2.5%	No	0.0%	BMP still needs access.
Site Clearing, Grubbing and Removals	4.1%	Yes	4.1%	BMP portion negligible in large project.
Utility Conflicts	0.9%	No	0.0%	May still have problems.
Environmental Mitigation	0.1%	No	0.0%	May still have problems.
Dewatering	0.0%	No	0.0%	May still have problems.
Buried Objects	5.6%	No	0.0%	May still have problems.
Safety/Security	1.5%	No	0.0%	BMP still needs fencing.

Traffic Control	3.8%	Yes	3.8%	Can piggyback traffic control on larger project.
Limited Space	3.3%	No	0.0%	May still have problems.
Limited Head	1.2%	Yes	1.2%	Can design drainage with rest of system.
Facility Restoration	2.3%	Yes	2.3%	Can coordinate activities to minimize disruption.
Miscellaneous Other Impacts	0.1%	No	0.0%	Unknown.
Totals	33.9%		**19.9%**	Maximum Reduction Expected

Therefore, as a possible upper limit for such cost savings, the 20% of applicable Site-Specific Costs were assumed to be pilot-unique for purposes of the Sharing of Costs category. Thus an upper pilot unique range of 20% of total construction cost for Sharing of Costs was established as shown in Table A-1. Note that these calculations do not account for possible savings from economy of scale line item costs for contractors (e.g., excavation, concrete, etc).

d) Scoping/Siting Study Limited to Caltrans ROW

Pilot Unique Table Text: Pilot study site selection was limited to Caltrans right-of-way (ROW) areas. Partnering with local jurisdictions may provide efficiencies of scale and reduce overall costs.

See *Size of BMPs* analysis below. Related to the use of larger-scaled controls.

3. Non-BMP Retrofit Costs

a) Additional Storage Bins .... Same as H&N evaluation.

4. Contracting Method

a) Lack of Competitive Bid

Pilot Unique Table Text: Prices appear to be inflated where few contractors bid on projects (e.g., only 2 bids received on Procurement Package No.2 vs. 4 bids on PS&E Package No.1 in District 12). In non-pilot program, will have flexibility to use PS&E (rather than more expensive Procurement) and reach out to more contractors, have better competition, and obtain superior bids with economies of scale.

All line items from Holmes & Narver's cost breakdown.xls spreadsheets were copied into one spreadsheet for all pilot projects available (32 projects). These line items and their associated quantities, units, cost/unit and actual cost were then sorted by item description. Any items with a cost/unit or actual cost of zero were deleted from the list, as these were headings and ancillary descriptions. Next, items with a unit of "LS" for lump sum or "FA" for force account were deleted, as these would not be comparable to units found in *Means® Heavy Construction Cost Data (2000)*. When a list was obtained that contained only line items with associated cost/unit, a new category was added of "Broad Description" in which similar items were put into the same general category and items that were the same but were listed under different titles would be sorted together alphabetically.

Means® Heavy Construction Cost Data was used to look up a comparable item for as many line item descriptions from the Caltrans pilot projects as possible. These *Means®* comparisons are general, planning level estimates. In most cases, where presented with choices from *Means®* and insufficient detail on the pilot project line item, a comparable item of high or the highest value was chosen to provide a conservative estimate. These comparative costs from *Means®* were then converted to the appropriate cost/unit to match Caltrans' metric costs and adjusted by a *Means®* geographical localization factor for Los Angeles. Final quantities from the projects were then multiplied by these Los Angeles adjusted unit costs to arrive at estimated costs for each line item. The sum of the estimated costs was adjusted to 1999 dollars and compared to the sum of the actual costs from the pilot projects. Forty-five percent of all line items were ascribed a *Means®* estimate. The adjusted *Means®* total was 27 percent lower than the Caltrans pilot project actual cost total for the same items.

This 27 percent factor was then entered into the H&N Breakdown.xls spreadsheets as the "Lack of Competitive Bid" factor for all BMPs in the pilot program. The breakdown.xls spreadsheet model then used this factor to adjust a number of items by this percentage. The resulting overall effect was to lower the construction costs of the BMPs by 26 percent. (Some items, such as pilot unique monitoring costs, were not affected by the "Lack of Competitive Bid" factor and thus the 27 percent *Means®* figure translated to a lower 26 percent cost reduction.) The 26 percent adjustment was thus used as the basis for a possible range of discounting *Lack of Competitive Bid* pilot unique costs by zero (0) to 26 percent as shown in Table A-1.

5. Experience of Designers

a) Standard Designs

Pilot Unique Table Text: Developing standardized design for the components of BMPs and establishing fast track review and approval procedures in CT system would the ultimate goals. However, these changes will require time. It is likely that greater efficiency in deployment, predictability for contractors, and lower overall cost would result from standardized BMP design packages.

Evaluation not prepared at present time. We anticipate looking at differences in cost between Delaware sand filters in Delaware and the unit installed during the pilot program. The state of Delaware has worked with designs and an approval process for precasting manufacturers to mass produce the chambers of Delaware sand filters on a more cost-effective basis than is likely achievable with a one-time cast-in-place application. Note that only some of the many BMP components potentially could benefit from this category.

b) Site Specific Designs

Pilot Unique Table Text: Anticipation, proper planning for site-specific BMPs such as infiltration basins which require special conditions, soils, etc. Costs associated with errors in designing and geotechnical should not be attributed to non-Pilot BMPs. Avoided with greater experience in BMP design.

Have not yet fully evaluated.

c) *Overdesigned Features.*

Have not yet fully evaluated.

d) *Vector Control Issues* ....*Same as H&N evaluation.*

6. Experience of Construction Contractors

a) *Construction Contractors Experience*

Pilot Unique Table Text: More competitive prices should be obtained once contractors gain experience, become more confident to submit lower cost, more competitive bids. [Unfamiliarity with BMP Construction]

See *Lack of Competitive Bid* analysis above. Note: does not imply that bids not competitive but rather that bid prices may have been higher than could be expected from more experienced contractors with more specialized experience.

7. Costs for Non-BMP Items

a) *Clear Blocked Storm Drains* ....*Same as H&N evaluation.*

b) *Traffic Safety* ....*Same as H&N evaluation.*

8. Quantity of BMP Pilots

a) *Field Crew Utilization*

Pilot Unique Table Text: Field Crew supervision staff (Superintendents and Foreman) could be more efficiently utilized, thereby reducing overall labor costs, if multiple sites were constructed under a single contract.

See *Sharing of Costs* analysis above.

b) *Material Costs*

Pilot Unique Table Text: Volume discounts may be possible for some material (Channelizers, Aggregate Base, Asphalt-Concrete, Pipe, Metal Beam Guard Rail, Temporary Railing) if multiple sites were constructed under a single contract.

See *Lack of Competitive Bid* analysis above. Note: does not imply that bids not competitive but rather that bid prices may have been higher than could be expected under different bidding scenarios.

9. Size of BMP Pilots

a) *Size of BMPs*

Pilot Unique Table Text: Certain fixed costs (such as Mobilization / Demobilization) are independent of the size of the BMP and therefore make up a larger percentage of the total cost for smaller units. Larger facilities would have a lower unit cost ($/acre-foot) since the fixed costs would remain relatively the same.

An analysis was performed to calculate the cost of implementing large-scaled pond BMPs. Large-scaled BMPs have the potential to offer more cost-effective treatment on a per unit treated basis. The following inputs and assumptions were used:

81.9	Total drainage area of all Caltrans pilot BMPs
85.0	Drainage area rounded up to nearest 5 acres.
$ 7,285,195	Total Pilot Program Cost (Base Cost plus Site-Specific Cost)
$ 6,500	Median National Cost for Wet Ponds per acre treated (see Section III)

The product of 85 acres times $6,500 per acre treated equals $552,500. This would be the theoretical cost of a wet pond facility serving 85 acres in Los Angeles *assuming no land acquisition costs*. This represents a 92 percent savings over the treatment of a like area by the combined pilot retrofit BMPs. Such a situation could occur where publicly owned land (e.g., a flood control facility) was already available for use as a water quality control. Any increase in land acquisition cost would increase the cost of the BMP. However, for purposes of an upper bound on pilot unique costs, this very low-cost scenario is relevant and has been employed by several jurisdictions around the US. The 92 percent adjustment was thus used as the basis for a possible range of discounting *Size of BMPs* pilot unique costs by zero (0) to 92 percent as shown in Table A-1.

b) *Equipment Costs*..*See "Size of BMPs"*

See *Size of BMPs* analysis above.

c) *Material Costs*...*See "Size of BMPs"*

See *Size of BMPs* analysis above.

10. Nature of Retrofit Construction

See *Sharing of Costs* analysis above.

11. Vegetation for Biofilters

See *Accelerated Time of Completion* analysis above.

12. Bid Procedures

See *Lack of Competitive Bid* analysis above.